CREST Best Practices Manual

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CREST Best Practices Manual
Chapter 1: Introduction

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1-01. Purpose and Intended Audience

This document is intended as a How-To guide for those involved in, or contemplating involvement in, the operation of a National Science Foundation-sponsored Center for Research Excellence in Science and Technology (CREST). Its purpose is to distill the existing knowledge and experience base regarding CREST start-up, operation and management into a resource tool for use by directors and other managers of prospective, new and established CRESTs.

In application, this information draws from approved primary references such as the NSF *Grant Proposal Guide* and the CREST program solicitation. Past and current CREST directors and CREST program staff have also been asked to contribute their ideas and suggestions to this manual. In principle and for consistency, this document also derives heavily from other best-practice manuals produced, such as those produced for NSF's Engineering Research Centers (ERCs), Science and Technology Centers (STCs) and Experimental Program to Stimulate Competitive Research (EPSCoR) projects. It is intended to be a "living" document, with regular updates and supplements as comments and suggestions for more comprehensive information are received. Consider this manual of best—really, "proven good" or "time tested" practices—as a guidebook to the spirit and intentions of the CREST program. Refer to it often as you prepare and submit a CREST proposal. Then, during the conduct of your CREST award, consult the Other Topics of Interest for Applicants and Awardees on the referring page, where more specific information is provide, parsed according to the point in the award process that it is needed.

Editor's Note—Throughout this guide, the term *proposal* is used to denote a research plan that is not yet funded, while *award* or *grant* is used interchangeably to denote a funded proposal, or *project*. *Program* refers to the NSF CREST program, while *Center* is used to refer to an individual CREST and its associated research projects. A *Cohort* refers to a group of awards made at approximately the same time. *Outputs* refer to deliverables of CREST awards (publications, patents, etc.), while *outcomes* refer to larger- and longer-scale impacts on the national community. A list of common abbreviations is also included in the appended materials of this manual.

1-02. Outline of the CREST BPM Materials

This best practices manual (BPM) is organized by chapter according to management roles. A separate Table of Contents and pagination is used for each chapter, to facilitate reader access to specific topics.

Chapter 1 provides an introduction and overview of the BPM.

Chapter 2 addresses the executive management of CRESTs.

Chapter 3 addresses the research management of CRESTs.

Chapter 4 describes the administrative management of a CREST

Chapter 5 describes the education and outreach programs of a CREST.

Chapter 6 describes industrial collaboration and technology transfer.

Chapter 7 discusses the CREST/NSF interface.

1-03. About the CREST Program

CREST was established in FY 1987 with the goal of strengthening the national research competitiveness of participating minority-serving institutions (MSIs) as well as increasing the number of underrepresented minorities awarded M.S. and Ph.D. degrees in science, technology, engineering and mathematics (STEM) fields. CREST currently represents fully half of NSF's support of research at MSIs in the United States. The number of CREST awards made year-to-year is a function of available program funding and the number of highly competitive proposals received. NSF's support for CREST is approximately $14 million per year. The average CREST award is $1 M per year (FY 2004), which reflects the average annual total operating cost of a CREST, and five years' duration, which represents the length of a CREST Cooperative Agreement. For years in which a CREST proposal competition has been held, the program's funding rate has ranged from 100 percent (in FY 1996) to 29 percent (in FY 2004).

Two CREST awards were made in FY 1987 as Cohort 1. Four Center awards were made in FY 1988 (Cohort 2), then 2 awards were made in FY 1991 as Cohort 3. Four awards were made in FY 1997 (Cohort 4), and 3 awards plus 1 research grant in FY 1998 (Cohort 5). Each CREST full award, under a cooperative agreement, is funded for up to $1 million per year for up to five years. A one-time renewal award for an additional five years is allowed for each Center that meets its goals and objectives. The first eight Centers—Cohorts 1, 2 and 3, initiated in FY 1987, 1988 and 1991—"graduated" from

the CREST program after 2 Cooperative Agreements and 10 years/$10 million in funding in FY 1997, 1998 and 2001, respectively. The FY 2002 (Cohort 6) CREST competition included 12 proposals, from which 3 Centers awards were made along with 3 renewals. The 2003 (Cohort 7) CREST competition included 17 proposals, from which 2 new Centers and 4 renewals were awarded. Thirty-six proposals competed during the FY 2004 (Cohort 8) CREST competition, of which 2 proposals were recommended for award along with 4 research grants (NSF EIS 2004). No new CREST Centers were supported in FY 1989-1990, 1992-1996, or 1999-2001 (see Table 1-01).

Table 1-01: CREST Centers and Renewals, FY 1987-2004

FY 1987 (Cohort 1)	FY 1988 (Cohort 2)	FY 1991 (Cohort 3)	FY 1997 (Cohort 4)	FY 1998 (Cohort 5)	FY 2002 (Cohort 6)	FY 2003 (Cohort 7)	FY 2004 (Cohort 8)
New Center Awards							
Howard University	University of Puerto Rico	Clark-Atlanta University	Florida A&M (not renewed)/Florida International University	California State University Los Angeles	Texas A&M Kingsville	Howard University	New Mexico State University
Meharry Medical College	University of Texas El Paso	Hampton University	North Carolina A&T State University	Norfolk State University	University of Puerto Rico - Rio Piedras	Florida International University (II)	Alabama A&M University (II)
	City College of New York		Tennessee State University	Jackson State University	CUNY City College		
	Alabama A&M University		Tuskegee University				
2	4	2	4	3	3	2	2
Renewals and Research Grants							
				New Mexico Highlands Univ. (grant)	Tennessee State University (renewal)	Cal State LA (renewal)	Fisk University (grant)
					North Carolina A&T State (renewal)	Jackson State University (renewal)	Clark Atlanta University (grant)
					Texas Engineering Exp. Station (grant)	Norfolk State University (renewal)	Hampton University (grant)
						Tuskegee University (renewal)	Texas Southern University (grant)
				1	3	4	4

Further details about CREST and links to past and current CREST awardees can be found at: http://www.ehr.nsf.gov/ehr/hrd/crest.asp

1-04. Current CREST Centers

CREST currently supports 13 Centers. These are presented in chronological order in Table 1-02.

Table 1-02. Current CREST Centers

Award	Title	Center Institution
0205803	Center for Advanced Materials and Smart Structures	North Carolina State A&T University
0206028	Center for Systems Science Research	Tennessee State University
0206162	CREST Center for Mesoscopic Modeling and Simulation	CUNY City College
0206200	CREST - Center for Tropical Applied Ecology and Conservation at the University of Puerto Rico-Rio Piedras	University of Puerto Rico-Rio Piedras
0206259	Research on Environmental Sustainability of Semi-Arid Coastal Areas (RESSACA)	Texas A & M Kingsville/Texas Engineering Experiment Station
0317607	CREST Center for Nanomaterials Characterization Science and Processing Technology	Howard University
0317692	CREST: Center of Emerging Technologies for Advanced Information Processing and High-Confidence Systems	Florida International University
0317722	Center for Photonic Materials Research	Norfolk State University
0317741	Synthesis, Manufacturing and Characterization of Structural Nanocomposites	Tuskegee University
0317772	Cea-Crest: The Center for Environmental Analysis of the California State University, Los Angeles	California State University Los Angeles
0318519	Computational Center for Molecular Structure and Interactions	Jackson State University
0420407	CREST: Center for Research Excellence in Bioinformatics and Computational Biology	New Mexico State University
0420541	CREST Center for Forest Ecosystems Assessment (CFEA)	Alabama A & M University

Details about any of these projects can be found by searching the indicated award number at www.nsf.gov. Further details about CREST and links to past and current CREST awardees can be found at: http://www.ehr.nsf.gov/ehr/hrd/crest.asp

1-05. HBCU-RISE

The Historically Black Colleges and Universities - Research Infrastructure for Science and Engineering (HBCU-RISE) activity (formerly known as the HBCU Doctoral Capacity Building activity) has been incorporated into the current CREST program solicitation. HBCU-RISE supports the development of research capability at Historically Black Colleges and Universities that offer doctoral degrees in STEM disciplines. Activities include, but are not limited to: faculty and technical support, faculty professional development, acquisition and/or upgrading of research equipment, collaborative research efforts with partner universities and national laboratories.

1-06. Chapter References

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CREST Best Practices Manual
Chapter 2: Executive Management

Contents

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EDITOR'S NOTE—This chapter is taken nearly verbatim from the Engineering Research Centers' Best Practices Web site (online at http://www.erc-assoc.org/manual/bp_index.htm), which may be consulted to compare and contrast with the CREST practices detailed below.

2-01. Introduction

The CREST Director is primarily responsible for the vision that determines the direction of each Center and inspires adherence to its objectives. As with most large-scale projects, there is clearly no single absolute and "best" way to direct a CREST—and if there were, NSF is not in the position of funding previously successful "recipes" for rote or "cookie-cutter" CRESTs, which would be contrary to particular user needs and, by extension, the national interest. However, a series of choices must be made in strategically charting the course for a CREST. Personnel, committees, facilities, bridges to the community and the interface with NSF and other agencies will all affect how a Center is perceived and whether it succeeds objectively and empirically (See Box 2-1: Profile of a CREST Director).

Every successful proposal, research project or Center must often revisit not only its own stated goals and objectives, but also those of the program providing the funding. CREST was established with the expressed goal to—

> Make substantial resources available to upgrade the capabilities of the most research-productive minority-serving institutions. CREST develops outstanding Centers through the integration of education and research. CREST serves to promote the production of new knowledge, to increase the research productivity of individual faculty, and to expand a diverse student presence in STEM disciplines. The program also enables CREST Centers to increase the effectiveness of related science and engineering activities within their research areas.

Accordingly, these are the questions a CREST Director must continually ask of his or her strategic plan: What is the current (and potential) research and education capacity of the institution or proposed alliance? How well are research and education integrated and complementary? How will productivity and the creation of new knowledge be measured and recognized? What are the participant demographics, particularly with respect to diversity? What lasting changes to the current institutional culture are possible with CREST funds and what significant contributions can the CREST make to the broader (national and international) research community?

Box 2-01: Profile of a CREST Director

Experience has shown that certain characteristics of background, ability, and personality tend to be associated with success in directing a CREST. This is not to say that NSF holds a fixed "ideal" of the model CREST Director. Certainly there is a range of characteristics and any given individual will be stronger in some areas than in others. In addition, the profile will vary across different fields, universities and industry bases. Finally, there are all the intangibles of team “chemistry,” timing and luck that may play as significant a role as any other more objective factor in one's ability to lead a CREST effectively.

- The individual will certainly possess the Ph.D. degree in a relevant field of engineering or science. He or she will be a university professor with teaching experience over a broad array of curricula and audience levels. Experience in working with industry is definitely an asset.

- The Director will be a tenured professor who is likely to have achieved widespread recognition in his or her field for scholarly and intellectual attainments. Age is not a factor; the person can be at early, mid, or late career, as long as he or she is tenured.

- Management experience in a setting analogous to the proposed CREST is highly recommended.

- In terms of leadership ability, five very important traits can be identified: 1) the ability to articulate a clear but flexible vision for the CREST; 2) cognizance with the current status of the field, a vision of future advancements and a strategy to achieve them; 3) the ability to integrate research from different fields to achieve a systems-level goal; 4) the ability to recognize intellectual needs and identify needed talents and form a sustainable cross-disciplinary team; and 5) the ability to recruit and lead without coercion.

- A Director will probably be someone who prefers to deal with the "big picture," rather than with details, and who knows how to hire and delegate the detailed tasks. It is also useful if the individual is a skilled "salesperson" in representing the Center's needs and capabilities to potential sponsors in industry and government.

- Team-building interpersonal skills are invaluable. Management in an

academic environment is often a delicate operation, so it is strongly advisable that the Director be diplomatic, tactful and empathetic as well as perceptive, alert and determined.

- Given the enormous demands of the job and the personal self-sacrifices it entails, the ability to make a total commitment to the Center is vital.
- The prospective Director must have gathered together a group of colleagues and junior faculty in relevant fields who are willing to form the core of the CREST faculty team. It is also important to have an industrial support base established through consulting, participation in a previous Center, industry employment, etc.
- Good relations with the university and departmental administrators, other federal, state, and private support bases (e.g., foundations) beyond NSF are useful.
- The Director should understand the opportunity the CREST provides to change the educational/research culture of the engineering efforts of the university and the potential to impact beyond engineering. He or she should be interested in integrating the results of the CREST systems perspective into the curriculum in new and innovative ways.
- A CREST Director should be a team-oriented coalition builder who welcomes change, since technological and cultural changes are inherent in the CREST mission. The Director's attitude toward the encouragement of women, persons with disabilities and underrepresented minorities to pursue STEM research must be genuinely positive.
- The Director should be oriented toward focused basic research that integrates science and engineering with long-term benefits for industry and education.
- Finally, the Director should be oriented always toward achieving a Center in which the integrated whole is greater than the sum of its individual parts.

2-02. Organization and Objectives

In order to avoid duplication with other chapters and to provide useful advice to incoming Center Directors, this chapter will address the conception of a

CREST, the daunting task of building and directing a CREST, and the set of decisions and actions that a new Director must take.

Early in the life of a CREST the Director must decide to what extent he or she will delegate responsibility for specific aspects of the Center's operations. He or she must then hire or assign employees or faculty members to fulfill these functions. Distance, communication and accountability between often separated and widespread components of the CREST must also be considered for coherence, duplication and omissions.

The new Director also must work to build harmonious relationships with the university's hierarchy and the relevant departments. This harmony may be jeopardized if, for example, the Director decides to press hard for contiguous space for the nascent Center at an early stage in its development.

Because not even the most heavily endowed universities can have all of the high-caliber faculty in the right areas that are necessary to execute the strategic plan of a good CREST, faculty recruitment is the most potent weapon that the Director has in hand to shape the Center. One of the Director's main contributions to the Center will, therefore, often be in the area of faculty recruitment and replacement, both externally and on campus. This contribution will extend throughout the life of the Center and will depend heavily on the relationships that the Director has built with contributing departments and with the university administration.

2-03. Creating the Strategic Plan

Every investigation or research agenda is based on a cumulative body of knowledge or thought upon which the researchers base their current understanding of a field and from which they draw a vision of how the current state of knowledge might be advanced. It is useful to begin by preparing a clear summary of the state of the art in the field addressed by each CREST, ideally complemented by a cogent needs assessment of the lead institution and desirable outcomes for all alliance members. The state-of-the-art summary of the research field should trace the development of the field from far enough in the past to capture the most important modern milestones in the field. This statement will be the starting point for the development of a strategic plan for the CREST. Later on, it will also provide a benchmark for assessing the progress of the Center and the value added to the field by the Center’s research and education activities. Accordingly, the extent to which the field has been presented in the classroom (successfully

or not) and the prospects for highly trained graduates in this area should also be considered.

Based on the historical developments in the field, each Center then creates a vision of what can be accomplished through the establishment of a CREST. Such a research vision should be based on the need for bringing various aspects of a particular field together to create the needed critical mass of interdisciplinary effort. The vision must be unique, or it will not strike a responsive chord in the NSF site review team that makes the initial recommendation for approval. The uniqueness of the vision will also have educational ramifications, because it is essentially a direct link from cutting-edge research to updating currently held understanding of science, technology, engineering and mathematics (STEM) disciplines. However, the vision must also be relevant to industry and of sufficient practical importance to favorably affect the competitiveness of this country, if it is to gain the imprimatur of the CREST program.

Since one outcome of the CREST program is to make a positive impact on U.S. competitiveness in the global marketplace, it is important to understand and articulate the potential commercial impact of a “successful” CREST. One way to make a case for the significance of the impact is to start with an extensive market analysis showing the size (current or potential) of the industry affected. If successful, will the impact be the creation of a major new industry? Is there an existing major industry in which the CREST expects to stimulate technical advancement and growth? Will the role of this CREST be central in the future of that industry? In the future of STEM education? These are all elements of the Center's vision.

A consensus vision statement is then prepared that is shared with all Center faculty and students. Each vision statement should identify the overall goals of the Center, not only in research but also in research, education and industrial interaction.

2-04. Participants in the Strategic Plan

The Director is the person in charge up upholding the vision on which each CREST is based and holding the alliance accountable for delivering on its goals and objectives. In many cases the Director is the author of the concept on which the CREST is based and the initiator of the application that obtained the original NSF funding. In the strategic plan, the research area leaders, Center associate directors, and key industrial representatives usually have input into the development of the vision and have achieved consensus regarding it.

Although the broadest possible "buy-in" to the vision is considered essential, it is difficult to involve more than this group of key individuals in these discussions. In some cases an incoming Director will have inherited the vision from its author(s). In either case, the key personnel must believe passionately in the vision on which the Center is based, and in the objectives of the CREST program before embarking on a multimillion-dollar Cooperative Agreement that may be funded for five to ten years.

As the originator of the vision of the CREST, the Director must be prepared to articulate this vision, in verbal or written form, to a wide variety of audiences ranging from local service clubs to an NSF site review team. The Director is responsible for "tracking" the vision of the CREST, as it is expressed in the literature and in scientific discourse, to guarantee that the Center is always at the cutting edge in research and at the forefront in the articulation of the perceptions that form the vision. Consequently, a Director must maintain continuously a clear perception of the linkages between the vision of the Center and its research, education and industrial activities and progress within them.

However, since it is essential that all participants in a CREST buy into the vision once it is articulated, it is useful to examine the sub-elements of the vision—in the form of the strategic plan and research plans—at regular intervals so that the faculty, students, and industrial members of a CREST community have the opportunity to become engaged with the vision and subscribe to it. In CRESTs that are narrowly based on specific, fast-changing technologies, it may actually be imperative that the basic vision of the Center be examined periodically, in cooperation with industry, and altered to suit the advancing state-of-the-art. However, most CRESTs are based on much broader visions, and here the role of the Director is pivotal.

Strategic plans are just that—strategies. Research areas can assume a life of their own and begin to consume their leaders' scientific and engineering passions, but Centers are only more valuable than the sum of the efforts of individual PIs if they contribute to achieving the Center's vision. It is the task of each Director to ensure that the vision is clearly seen and well served by the Center through integrated research and education. In fact, it is a requirement of the CREST program that the integrated whole of the Center be greater than the sum of its individual parts.

2-05. Implementing the Strategic Plan

After developing a broad strategy for achieving its vision, How can a cross-disciplinary Center take advantage of the opportunity envisioned? This is its mission. Is it realistic? Does the CREST have the necessary intellectual horsepower to achieve success in this area? One way to answer these questions is to convene a panel of objective outside experts to evaluate the plans and personnel of a proposed CREST. If the answers are encouraging, then the next step is to develop a strategic research plan to achieve the vision and mission.

In contrast to the process of originating the Center's vision, the process of strategic planning is more democratic. In some Centers, the initial planning is done by an executive committee consisting of the Directorate (including associate directors, if any), research leaders and/or senior faculty, and key staff such as the education and outreach directors. A smaller group allows faster convergence on the initial plan. But in most Centers the process involves, either at the outset or subsequently, discussion and input from all faculty members and research staff. Usually the plan is reviewed and discussed at least annually by the Industrial Advisory Board (or equivalent). It can be challenging to avoid the natural tendency of industry to direct the details of the plan toward areas of short-term interest; the Director must be vigilant to filter out such influences and absorb them in the higher aims of the plan.

Revision of the strategic plan at the level of research areas is almost continuous in most Centers. Adjustments are made to specific goals and short-term approaches through frequent meetings of the Director, the research leaders, educators and PIs in that area. Strategic research planning at this level is discussed in Chapter 3.

2.06 Structuring the Center for Success

Delegation and staffing during the life cycle of a CREST is an issue of fundamental importance. The related questions of how much to delegate, what management and operations functions to delegate and how best to accomplish this distribution of responsibilities should be addressed in the planning stages of the CREST. It must then be continued into the initial stages of funding and implementation of the CREST proposal.

The structure of the Center also determines directly how well its participants and its various research areas will interact to achieve the cross-disciplinary flavor inherent in a successful CREST.

2.07 Delegating Responsibility

When a CREST is funded, it is probable that there will have been a persuasive individual who has initiated the application and gathered the research team. It is equally probable that this initiator will have a large and well-funded research group. But it is apparent that the duties of the Director of a CREST are sufficiently challenging that they are very difficult to combine with those of a successful and busy individual unless the person concerned is adept at delegation.

Directors of CRESTs form a variety of models in this regard, ranging from the "one-man band" to the "master delegator." Some have gradually increased the delegation of responsibilities as the activities have become more routine and the CREST takes flight. If the Director delegates too little responsibility, he or she risks "burning out" losing at least some motivational or persuasive skills and at most the loss of his or her own research program or even the Center itself. If too much is delegated, tangible control of the Center may be lost, jeopardize its ultimate success. There clearly are some instances in which a strong and well-balanced group of researchers persuades a faculty member with experience in administration to assume the directorship of a nascent Center. These Centers start with an advantage because the new Director will probably already know how to delegate effectively, but it is only advantageous if the Director is or can become the intellectual leader as well.

The founding Director should assess the importance of all the potential roles within the Center and decide which to delegate and which to retain. Three major factors must govern the Director's choice of areas in which to concentrate attention: the peculiar strengths of his/her Center team, the

overall interests of the Center and, finally, the meshing of his/her own research interests with the interests of the Center. In any case, the Director's research must fit integrally within the scope of the Center's research or it may be seen as a conflict of interest and a threat to the cohesiveness of the Center. Such conflicts are viewed as serious by NSF, and must be resolved quickly.

Administrative Management—If the Director chooses to retain control of administrative and routine personnel matters, he or she will drown in details as the Center grows to contain dozens of people. If the Director retains direct, personal control of financial matters, he or she can use this control to steer the Center in detail, but the Director will be held responsible for every fiduciary concern and will encounter resentment when support is withheld or withdrawn. Experience teaches that, given the efficiency of sole autocratic command, a researcher can control and steer a research group of about 40 with some help from experienced staff and postdoctoral fellows. But an integrated Center with numerous faculty members and dozens of students is simply too large for one person to manage effectively. The sole exception occurs when a Center becomes an "on-campus granting agency" and parcels out NSF funds and industrial money to fully independent PIs who run their own labs in the time-honored way, while the Director runs his or her own operation and acts as the reporting Center. However, this approach is contrary to NSF policy and subverts the purpose of the CREST program; such a Center will not last long.

Over time, it has become apparent that the CREST Director can be aided in this complex role by a deputy executive officer who shares some of the leadership and management responsibilities in the CREST, in a manner that complements the leadership style of the Director. The Directors of existing CRESTs without a Deputy Director or the equivalent should give careful consideration to hiring a Deputy.

Because a CREST with NSF funding and average industrial, state and university support constitutes a $5 to $10 million enterprise, at least a basic administrative structure is mandatory for effective organizational and financial responsibility. Since the Director has, by necessity or by choice, probably delegated much of the administrative responsibility to trained specialists, the Center will be shaped by the choices that are made in setting up this structure.

All CRESTs have an Administrative Director (AD), or the equivalent, who is responsible for general management of the day-to-day operations of the Center. The Director and the AD typically work very closely together; the smaller the administrative staff, the more this tends to be the case. The position of AD requires a strong generalist, and selection of the right person is critical. These individuals play a key role in the overall success of the Centers. It is essential that the AD understand fully the vision of the Center, its ideals, and its intended impact, and that s/he be treated as a partner in bringing them to fruition. The AD accepts the responsibility of implementing the Center's vision in a manner acceptable to the university's bureaucracy. There must be a mutual respect, with the Director articulating the concepts and ensuring buy-in and the AD providing a reality check on what is possible and identifying ways to implement the concepts.

It must be noted, however, that the Director is ultimately responsible for any administrative lapses that may occur; consequently, it is important to maintain supervisory oversight and control of office management functions. One potential danger inherent in a smaller Center structure is that the Director may delegate too much authority to the AD. The Director and AD may then mutually reinforce each other's belief that "everything's fine," even if administrative problems have begun to appear.

The decision to hire specialists for other functions will affect the Center in various ways. If an assertive accountant is hired, the finances of the Center will be well managed; but at an extreme, account management may not be as flexible as the Director needs it to be to accommodate frequent changes in the strategic plan and new developments that demand shifts in resources. If a computer specialist is hired, the Center will have excellent data handling, good communications, and an attractive presentation on its Web page. If the industrial interface is handled by administrative staff on a part-time basis, the Director will be the *de facto* salesman for the Center. On the other hand, if an aggressive industrial liaison officer and technology transfer specialist is hired who can convince the PIs to buy into the industrial interface, the industrial interface will burgeon and there will likely be a strong technical connection with industry through the PIs. If a part-time education committee manages the details and the policy of interdisciplinary education in the Center, students will be trained in their home departments and assembled in the Center for occasional seminars and NSF site visits. But if an imaginative and personable education specialist is appointed, the students will make their home and form their friendships and loyalties in the Center—and may be able to fund their own education with competitive scholarships.

The administrative infrastructures of Centers thus range from a few people gathered tightly around the Director to small armies of specialists working for the benefit of the Center, and each choice that is made will affect the kind of Center that will emerge at the critical third- and fifth-year review milestones. The choices made in setting up the infrastructure of the Center are matters of policy, and not of financial expediency, because at least two of the key responsibilities (technology transfer and education) may become largely self-funding. The administrative structure of the Center must be set up thoughtfully by the Director, who must ensure that all major policy matters remain firmly under the control of Center leadership and are complementary to the primary objectives of the Center—industrially relevant cutting edge research and team-based interdisciplinary education.

The size of the administrative teams that run the daily affairs of CRESTs varies between 3 and 9. The Director who chooses the smaller, "tighter" option will retain more control over the operations of the Center, because he or she can readily meet with the key people and set policy through direct conversation. The expanded team will offer greater possibilities for growth for the Center, and for participation by more of its members, but the Director will probably have to relinquish some personal control and may be forced to appoint an overall manager from among this large group of Center employees--or, preferably, to bring in a Deputy Director or Executive Officer. Administrative teams are easy to expand but difficult to contract; like many well-established units in industry and government, they often have an effective life of their own and a strong instinct for self-perpetuation. For this reason, the establishment of a large team constitutes a commitment to the Center, on the part of the Director and the university administration. This commitment itself may drive the conversion of the CREST to an ongoing research/education entity after NSF support is terminated.

The three pillars of the CREST program are research, education, and technology transfer. However, it is clear that the first (research) is a *sine qua non*, in that there are no educational or technological advantages to be gained from research if it is not outstanding. On the other hand, the applications of even the best research will be limited if it is not transferred in an engaging way to the classroom or industrial facility.

If a CREST is to be a "better idea" Center, rather than a "where do we get the money?" Center, there must be a clear linkage between the strategic plan and research management and another linkage between research management and the management of finance and of education. In other

words, decisions about the investment of Center resources in specific research projects and in the support of students in specific research areas must be guided by a strategic plan in which the Center is united. When decisions have to be made about how resources should be allocated to the various research areas, the Director will find himself in a situation that will be dictated by choices he or she has made at the outset. Either there will be a clearly stated strategic plan that makes the finance committee's job possible, or there will be a struggle for funds and the Director will have to make all of the final decisions.

If there is a clearly stated strategic plan, the Director should be vigilant to discern the real authorship of key inputs to that plan. The strategic plan of a Center can be manipulated by a small group of faculty with preconceived notions of what direction they want the Center's research to take or, at an extreme, by a single strong personality—often the Director—who simply tells the troops that this is what has been decided. The smaller the coterie of influential insiders, the more NSF money there is for each individual in that group. But NSF site visitors can detect such a situation fairly easily and will not tolerate it. Effective strategic planning can prevent this tendency toward centralized self-interest.

Research Management—Chapter 3 deals specifically and in detail with research management in a CREST. However, management of this activity is central to the overall management and direction of a CREST and impinges on the success of every other area of Center activity. The discussion here addresses research management in this broad context.

Research in a CREST is inspired and directed by the Center's vision, as articulated by the Director and as supported by its members. The practical vehicle for the realization of this vision is the strategic plan, and the mechanism for its execution is the structure of research areas and testbeds found in most CRESTs. The Directors of most CRESTs maintain firm control of the Center-level strategic planning process; most decisions in research management are made by these Directors with the advice of a small inner circle of senior Center researchers who comprise an executive committee. Several respondents regretted the lack of involvement of junior faculty in both the strategic planning and the research management processes, but cited difficulties in involving large numbers of people in these decisions. In general, the responsibility for the planning and management of research remains centralized. At the detail level, however, junior faculty and students are more often involved in setting goals and milestones.

The most common and efficient apparatus for research management appears to be the appointment, by the Director, of a limited number (no more than five) of thrust area leaders who then join a few senior faculty colleagues to form a research steering committee. This "closed" structure is inherently efficient, in terms of both reporting and decision-making, but it can stifle the growth and renewal of the Center because it can be very difficult for new people and new research ideas to break into this exclusive club.

There may be difficulties in closing down existing projects. Most CRESTs report that they depend ultimately on the Director to make these hard decisions, but such CRESTs have closed research management structures that may require that the research committee vote against one of its own members in order to accomplish this essential revitalization—a process that is inherently conservative. Involvement of the IAB is said to be critical, along with the objective judgment of the Director, in overcoming the tendency of the well-entrenched "old boy's club" to maintain the status quo. One Director notes that these decisions are not made overnight; first, the need for action becomes generally recognized and then action is taken. It is easier to terminate unsuccessful lines of research if there is a detailed strategic plan with milestones; this makes it apparent when a project is going nowhere and/or no longer fits within the strategic plan.

It is important to begin with the right number of research thrust areas. The "right" number may differ from Center to Center and field to field, and may also change across time. However, in general the fewer the research areas, the easier it is to manage the research program.

To facilitate the growth of a CREST and the realization of its vision, the Director should set up effective mechanisms for the intake of new people with new ideas. Because most Center Directors have actually sacrificed or heavily modified their personal research programs in favor of the Center's interests, these people have both the motivation and the detachment necessary to welcome new talent into their CRESTs. In most cases the Director is well advised to make the intake of new people, who are necessary for the realization of the Center's vision, a very personal affair. They can be scouted, on campus or by recruitment, and their work can be steered toward the Center's interests even before they are introduced to the CREST. They can then be invited to give seminars in the Center's programs and/or invited to CREST retreats, to see if their fresh ideas strike a responsive note with the Center as a whole. If so, they can then be brought into the Center, where their presence and their new ideas allow the Center to breathe fresh air.

A CREST is an excellent power base because it represents a large amount of research money, and it will attract those who are interested in wielding financial power. The Director of a CREST must make a choice as to whether he or she will become the sole power broker, the leader of a small and select coterie of power brokers, or the arbiter of power who balances the process for the good of the Center. A lesson learned from the management of research Centers is that even the most promising Center, founded on the most talented team of researchers, needs a constant flux of new people and new ideas to keep its edge. All Centers try to stay ahead of the curve by recruiting excellent graduate students and postdocs, but very few give newly recruited faculty members senior positions with real access to Center resources (especially if they are from outside the university). It is clearly NSF's intent that each individual CREST should continue as a research/ education/ technology transfer entity long after its support is terminated. The CRESTs that we build must be built to last. For this reason, the Director of a CREST must resolve to build an effective faculty intake mechanism into the Center, including the possibility of recruiting beyond the home university. He or she must select the new team members with exquisite care and choose research management structures that allow the newcomers to share power and resources on an equal footing with all other participants.

It may be useful for the Director of a CREST to remain somewhat removed from matters of research management through the appointment of an Associate Director for Research and/or a research steering committee. This delegation of responsibility for the day-to-day management of research, and for the research reporting function that looms each year in the CREST program, can leave the Director free to serve as custodian of the vision and as the chief arbitrator of the strategic plan. The research apparatus of the CREST is directed by the strategic plan. For this reason the strategic planning process is the ideal level at which new ideas should be introduced into the Center's research. If the full membership of the Center, including new faculty recruits and peripheral members who would like to become more integrated, have the opportunity to make meaningful contributions at the strategic planning level, the Center can become a living, evolving community.

Rather than making all research management decisions personally, a CREST Director may find it more useful to maintain the vitality of the Center by making sure that all ideas that serve the vision have an equal chance of implementation. It is certainly not the intent of the CREST program to provide 10 years of high-level funding to a Director and an unchanging group of researchers, however capable and even brilliant they may be. Thus, a new

Director must decide whether he or she will retain complete personal control over research management, set up a closed system of research management involving a select group of insiders, or augment the closed system with strategic planning and revitalization mechanisms that involve the whole Center. Perhaps there is no choice to be made by a new Director, in the initial stages of the organization of a CREST, that will affect the Center more than this pivotal decision.

Education Management—One of the three pillars of the CREST program, education is the element with which most Centers feel that they have had the greatest success. This success may reflect the national need for education of interdisciplinary team-oriented Ph.D.s, more than the effective policies and programs implemented by individual CREST Directors; but in any case it is a very fertile area that may come to dominate the future of individual CRESTs and even of the CREST program itself. Because educational policies take so long to come to fruition, it is probably wise for the Director of a new CREST to study the history of education in the CREST program and to make choices early in the life of the CREST that will allow this natural process to happen.

The basic responsibility for education rests with the traditional university departments; the most that a CREST can offer to the undergraduate or graduate student is an enhancement of their education. A CREST Director must decide, very early in the life of the Center, how much to coordinate with the alliance's departmental graduate programs. This coordination may be detailed, such as scheduling seminars to avoid department/CREST conflicts, or broad, such as establishing the proper balance in competing for the department's pool of graduate students; but in any case the spirit is more important than the details, and good relations are important.

Contiguous space for a CREST is highly desirable, but the extent of this difficulty and its resolution are very different from campus to campus. Whether or not the CREST Director becomes engaged in the university "space wars," the success of the CREST education program depends upon collegiality—often including informal or recommended "tiered mentoring"—among CREST students at all levels of their university experience.

The Director of a CREST must realize that the Center's vital crop of interdisciplinary, team-oriented, industry-friendly graduates is dependent on many factors outside of his/her direct control. If the Director chooses to be unfriendly toward the departments who have students affiliated with the Center, he or she can expect the graduate committee of each of those

departments to raise major difficulties about the balance their students must strike between the department and the Center. If the Director is fair-minded about departmental imperatives (like obligatory teaching assistant assignments), and if both the department and the Center hold the student's interests to be paramount, a mutual trust will develop that will let the CREST "thing" happen. The CREST "thing" is unique in most universities, and it involves an enriched and very challenging interdisciplinary education for a limited number of excellent students who reflect credit on both their department and the Center.

In an area such as education, in which the CREST can facilitate but not dictate, the Director must exercise great care in setting up program structures. The appointment of either a part-time faculty member or a full-time professional as Education Coordinator will greatly facilitate the recruitment and integration of both undergraduate and graduate students into the Center. This person may also handle the laborious logistics of the Center's seminar and internship program(s) and the educational reporting requirements of sponsors. An experienced Education Coordinator should know the students well enough to flag cases in which the student is confused and/or troubled by conflicting demands of the Center and of his/her home department, or by any of the myriad problems that beset the engineering acolyte today.

Because a mature CREST may involve 40 to 60 undergraduate and 60 to 80 graduate students, the Director cannot begin to involve himself in either their personal or collective supervision. For this reason it is advisable to appoint an education committee whose chairperson works closely with the Education Coordinator. In this way each student knows that the Center provides a professional and a faculty member that they can contact with any problems, while the Education Coordinator and the rest of the committee serve the Center by advising the Director on policies that affect Center students.

While the CREST pattern does not fit precisely into the educational structure of the modern university, it may comprise its salvation. The CREST Program has pioneered interdisciplinary, team-oriented research, and it has a lot of experience in both the pitfalls and the benefits of the "new" paradigm currently being endorsed for both science and engineering education at the highest levels of national policy. This very important paradigm shift is of considerable interest to the NSF and, as the most successful of its programs in this respect, the CREST program may see fit to base a large element of its continuity on its accomplishments in the area of education. If this

assessment is correct, as the CREST moves to self-sufficiency, individual CRESTs may find a very successful interdisciplinary education program to be a large factor in their continuity within their own university environments.

Management of Technology Transfer—Technology transfer is the fourth pillar of the CREST program. It is axiomatic that most academics feel that technology transfer is something that they could easily do, without any special training or experience, if they could just spare time from their well-understood responsibilities in research and/or education. Perhaps it seems to many of them to be simply a matter of a few simple phone calls and of taking a little time with the industrial people who regularly beat a path to the doors of their institutions.

This perception may be the key to the inability of American science and engineering to make a real impact on American industry, and this perceived problem was a large part of the rationale for the creation of the Engineering Research Centers program in 1984. CREST is essentially an attempt to do the same thing at minority-serving institutions. The subject of Industrial Collaboration and Technology Transfer is covered at length in Chapter 6. The treatment of this topic here is from the standpoint of overall Center management and direction.

The Director of a new CREST is likely to be committed to research, or s/he would not have been successful in being funded. However, there is no guarantee that the new Director will have the same level of commitment to technology transfer. For this reason there is an especially wide range of choices that the Director will make in the early stages of the Center's development that will affect the degree to which the Center will be able to present its vision to industry for practical exploitation. At a minimum, the Director may use the academic workshop mechanism to collect a group of companies to form a paying audience in the applicable field, and then simply allocate a couple of articulate graduate students to give tours of the Center in their spare time (although this approach will almost certainly fail to produce a successful industrial program.) Alternatively, the Director may designate one or more of the Center PIs who are already well connected to industry to handle company recruitment and meetings of the Industrial Advisory Board (IAB) or its analogue—although this approach, too, is not ideal. The technology transfer area does not seem to lend itself to management by a committee, and none of the respondents to our survey reported the formation of a committee for this purpose. If the incoming Director is personally committed to the process of technology transfer--as

befits a CREST Director—he or she will take a very active role in company recruitment (also vital to Center funding), in interacting with the IAB members, and in developing opportunities for joint research with sponsoring companies. And if s/he is serious about technology transfer, s/he will also hire a Director of Technology Transfer (often called an Industrial Liaison Specialist) from outside of the academic framework. The ILS will be given the freedom to build meaningful relationships on an ongoing basis with companies interested in the Center's technology.

The technology transfer "portfolio" really cannot be separated from the research and education elements of the Center, because CREST research should be cooperative with industry and industry should play a very active role in the education of students (e.g., through internships). Ideally, the Director should be fully committed to technology transfer, and should consider activity in this area as integral to other activities in research and education. S/he should ensure that the directors of education and technology transfer work well together and strive to coordinate their program activities where appropriate. S/he should work very closely with the Center's Director of Technology Transfer, and with people in similar positions in the university, to move Center technologies directly into that part of American industry that will benefit the most. The incoming Director will have telegraphed the extent of his/her commitment to technology transfer to the new Center's member companies within the first 18 months of the Center's operation by the choices that s/he has made to staff and activate this vital element of the Center.

2-08. Mechanisms of Delegation

Sometimes just as important as the degree to which the Director delegates responsibility within the Center are the mechanism(s) of delegation. In the administrative area, economy dictates that individuals be allocated specific responsibilities, such as computer networking or accounting, and then be reinforced with less trained personnel when their workloads become undesirable. An important early decision must be the type of supervision and reporting to utilize for the Center’s administrative staff. There is clearly a limit, which is dependent on the personality and policies of the Center Director, to the number of Center employees who can take detailed direction from this one source. The alternative is to have all administrative staff report through another designated individual (a Deputy Director, Executive Director, or Administrative Director).

This delegation should be done very carefully because its consequences for the smooth operation of the Center are likely to be quite significant. Everyone involved in a CREST must realize that the Center's vision and strategic plan drive the whole exercise. The administrative function is only an "engine" (albeit an essential one) to facilitate the realization of the vision and, as such, it will always be secondary to the program activities of the Center. A simple rule of thumb is that the administrative structure of the Center should always be elastic (but structured). Flexibility is also important when establishing a reporting structure, because it may be difficult to assess realistically in advance how large a staff might ultimately be in place.

Education issues are often course-specific and/or student-specific. Many call for wisdom and mature judgment while revolving primarily around the interests of the students concerned. Hundreds of hours can be spent in the resolution of these issues; therefore, in some Centers an education committee with an active and very accessible chairperson may constitute the best use of faculty time, provided that the Education Coordinator handles most details. In other Centers the Education Coordinator has more autonomy in decision making about course-specific and student-specific matters, looking to the Center Director and/or an education committee for broad policy guidance.

The reporting requirements of the CREST program review process virtually demand that each Center must appoint a leader for each research area and that someone, usually the Director, must combine these reports with those of the education and technology transfer programs to produce the annual report. These research area leaders also provide a necessary management interface between the Director and the faculty researchers, with responsibility for the detailed planning of research within that area. The research leaders, perhaps with the appointment of an overall Associate Director for Research, would seem logically to constitute an efficient committee for the planning and execution of the Center's strategic research plan. To ensure the periodic introduction of new people, new ideas, and new projects, the Director may choose to create an uptake mechanism whereby the Center can be revitalized. This enterprise can take many forms—for example, a committee that emerges from a full meeting of the Center (perhaps a retreat) and has the mandate of examining and possibly amending the Center's strategic plan may be useful.

2-09. Principles of Delegation

Delegation of responsibilities is not an art that is peculiar to directing a CREST, and the basic principles that govern this important process are well established. Delegation should serve the personal interests of all parties involved, and it should always be voluntary within the academic context. A Director should consider the career path of all concerned, and should avoid overloading individuals or saddling young researchers with responsibilities before they are ready. Once a specific responsibility has been delegated, the Director should avoid interference or micro-management. The Director should attempt to balance responsibilities within the CREST so that no single individual acquires excessive power and thus negatively impacts the contributions of other members of the Center. People to whom responsibilities are delegated should have a clear idea of what is expected of them and of the length of time for which they are committing themselves. Most of the academics that make up the faculty of CRESTs also have a base in their home departments, so that a CREST Director is really running a volunteer operation. The Director has the seductive power of his/her vision of the CREST, with certain financial resources at his/her disposal, but s/he does not have the power implicit in a direct "chain of command," so it is necessary to exercise considerable diplomacy in the process of delegation.

2-10. Continuity of Leadership

One area of delegation that should be mentioned concerns the ultimate delegation—that of the directorship of the Center. Succession is an issue that many ambitious executives, in academe as well as business, find difficult to address. If one is performing well and enjoying oneself as a Director, it is perhaps counter-instinctive to make plans to replace oneself. Nevertheless, as a responsible manager with a major investment of energy and commitment in the Center, it is only prudent to provide a viable contingency plan for one's succession and thereby minimize the turbulence that would ensue in the event of the Director's departure.

An appointed Deputy Director or an Associate Director (often for research), will often take over the leadership role until a search can be organized to select a new Director (who may or may not be the deputy). This is an individual who routinely takes some of the Director's workload in managing aspects of Center function. He or she has a seat on the Executive Council or equivalent and may have a large role in tracking and management of the Center's strategic plan and/or interactions with the industrial advisory board.

2-11. What *Not* to Delegate

There is general agreement among CREST Directors that the following responsibilities should *not* be delegated.

- Major resource allocation and budget decisions, including fiscal oversight.
- Major realignment of Center administrative and research structure.
- Final decision on hiring (and termination of) faculty and key staff.
- Final selection of companies to recruit as members.
- Formal contacts with NSF to address major issues.
- Policy interactions with department heads, college deans, and university top administrators.
- Negotiations with university administrators for commitments of resources.
- Integration of the CREST's annual report to NSF.
- Responsibility for the integrity of the CREST's reporting systems.

These clearly are functions and decisions that directly affect the health and continuing success of the CREST. Missteps could be quite destabilizing. As such, responsibility for them should rest with the individual with the lead responsibility for overall Center management, the Director.

2-12. Facilitating Cross-Disciplinary Interactions

Individual CREST and ERCs have devised many ways to facilitate cross-disciplinary interactions among the faculty. In a number of Centers an absolutist approach is taken: i.e., projects without cross-disciplinary interactions will not be funded through the Center's resources; or else the evaluation criteria for project continuation include cross-disciplinary collaboration. In other Centers the requirement is not so absolute for all projects, although there is a strong preference for cross-disciplinarity and a strong message is given that collaboration is necessary if the CREST is to be successful.

Other mechanisms that are employed to encourage and facilitate these interactions include:

- Specific requests for collaborative research to meet an identified need;

- Special Center funds made available for cross-disciplinary projects and proposals;
- Inviting researchers from a range of fields to Center research meetings and retreats;
- Structuring Center research so that project teams cannot complete their assigned projects without obtaining assistance from other teams;
- Developing a set of "end-to-end" demonstrations, within and between research clusters, that illustrate how the tools and methodologies work together; and
- Engaging in design activities with Center industrial affiliates (which commonly involve participants from more than one project or research focus).

Directors report that the advantages of cross-disciplinary interactions include: the ability to address technical barriers that could not be overcome in any other way; intellectual challenge and stimulation; and a broader perspective available to faculty and students. The disadvantages are that: cross-disciplinary work requires more time and effort to understand the perspectives of colleagues from other disciplines; departments sometimes do not credit such projects in promotion decisions (this is where input from the CREST Director and the support of the Dean are critical); and faculty may have trouble obtaining individual credit, which they need to obtain promotion. Thus, the disadvantages are systemic, but can be overcome, and in any event they are outweighed by the advantages of this type of research to industry and the Nation.

2-13. Locating Necessary Resources

Operating a well-run CREST involves bringing together the necessary resources, including not only personnel but also facilities and funding. Facilities required to carry out the CREST's research mission include so-called signature space for housing the Center administrative offices, conference room, and general space for Center-supported activities such as a computer laboratory, student library, and lounge where faculty, students, and staff can gather to discuss their work. Distributed laboratory space is necessary for developing basic materials, device, and system-level competencies. Usually

the Dean of the College of Engineering and the chairs of the individual departments make the signature space available to the Center. Individual laboratory space is usually made available to faculty on a have-need basis.

Once the space is available, some remodeling is usually required. Generally these resources are obtained from indirect cost recovery (ICR) money. Equipment to outfit the space can be part of the CREST award, or acquired through any number of government equipment grants including those of NSF, or the Department of Defense, industry, and philanthropic foundations.

When considering the Center's funding profile, it is important to maintain balance. For example, if most of the Center's funding is from NSF, then the relevance to industry is somewhat suspect. Within industry, it is best to develop a diversified portfolio of partners ranging, if possible, horizontally across various industries and vertically from raw materials producers to parts suppliers to system manufacturers. If all the outside funding is from one industry, then there is a certain vulnerability if the particular industry goes through a bad patch. A balance between state and various federal government agency and industry funding is desirable, because no one sponsor or sector has an undue influence over the activities of the CREST.

2-14. Avoiding Failure, Pursuing Success

There are many kinds of problems that can lead to failure for a CREST. Difficulties in leadership and management (including financial management), problems in research planning and execution (including disintegration and failure to address its vision), and failure to engage with industry positively and in the proper ways are all sources of serious trouble. These are higher-order issues that are addressed throughout this Manual. The most prevalent approach to reducing the excessive burden on the Director is to add a Deputy or Associate Director; key staff members such as the Industrial Liaison Specialist and the Education Coordinator also remove some pressure. Several Directors point to the enormous importance of having an Operations Director or Administrative Director who is capable of handling many of the day-to-day operational tasks. Nevertheless, as one Director says, "The specter of burnout is ever-present."

Although pressures are greatest on the Director, burnout of other key personnel within a CREST is also a concern. Suggestions for alleviating this risk include the following:

- Rotating standing assignments such as thrust area leadership and seminar planning;
- Rotating people and responsibilities in conjunction with the university; and
- Planning more thoroughly so as to reduce the number of distractions and unproductive activities.

A CREST represents a new type of organization in academe. At each university where a new CREST is established, the members of the CREST faculty and staff generally have to feel their way along in forming a cohesive team. Effective leadership from the Director is indispensable to this process. However, formal training in team-building and organizational interaction in this novel setting can be highly effective in speeding the development of these skills.

Rewarding Center participants for strong performance is an excellent morale-booster and an incentive for further success. Many kinds of reward are available for Center Directors to bestow. One of the most prevalent and effective is continued or increased research support, including seed funding; increased compensation is of course one mechanism. Additional travel funds for making presentations at conferences can be provided out of Center unrestricted funds, as well as scholarships and fellowships. Increased visibility and support for making presentations at program reviews is appreciated as a career-enhancer. Success should also, of course, lead to promotion and tenure for junior faculty in the Center. Several of the Centers nominate their deserving staff for university awards and undergraduates for university-sponsored project awards.

2-15. Recruiting

The most powerful tool available to a CREST Director is the vital process of faculty recruiting. This process starts with the formation of the team that will assemble the initial CREST proposal and includes all subsequent new-faculty and on-campus recruiting, as well as (often) the involvement of faculty from other institutions on a project basis. The Director's role is clearly pivotal in all important aspects of the Center's success. All of the "superstars" of the academic world will be on hand to watch the Center (and its attractive research budget) develop, along with the workhorses and brilliant but more humble members of the university's departments. The new Director must

realize that personal habits are deeply ingrained, in academe as elsewhere. The brilliant researcher who tends to be critical and superior in his or her attitude toward colleagues and the Department Chair will probably soon adopt the same attitude toward the Center faculty and Director. Effective administration of any research enterprise calls for a careful balance between the prima donnas and the sometimes equally talented workhorses, and the new Director should carefully select those individuals who are committed to working toward the success of the Center and not just toward the furtherance of their self-interest.

On the other hand, the Director must hold to his/her vision and keep the objectives of the CREST program in mind; to do that, he or she must recruit faculty who can build a truly world-class research team. Ignoring education and technology transfer is injurious to the Center, if many of the faculty are permitted this luxury. Perhaps the most prudent litmus test the Director can apply, throughout the process of recruiting, is to project his/her honest enthusiasm about all of the Center's activities. He or she must listen very carefully for any signs of arrogance or superiority—attitudes that do not mesh well with the team culture of a CREST.

The dedicated band of true believers that surrounds the prospective Director rarely survives intact to form the nucleus of the funded Center. For this reason, the movers and shakers who constitute the university's critical mass in the chosen research area will serve as a good platform on which the prospective Director can begin to focus and define his/her vision of the embryonic CREST.

The eventual interdisciplinary nature of the CREST will be determined largely by the strategic plan and the composition of the organizing group. If the prospective Director proposes to involve departments outside of Engineering in the CREST, he or she will be well-advised to approach Deans and Department Heads for their support before attempting to recruit faculty members and graduate students into an enterprise that their own line administrators have not yet had a chance to buy into. To recruit the latter, without enlisting the support of the former, constitutes a serious threat to the career objectives of talented young people. Perhaps the rule of thumb is to make the strongest possible case, to recruit the best people, and do whatever is necessary to make sure that no damage is done to the career of anyone drawn into the orbit of the Center to serve its vision.

It is vital to have an established research alliance and a watertight memorandum of understanding (MOU) if the allocation of research activities to affiliate institutions or PIs is to be successful and the activities are to be well-integrated with the Center's educational and technology transfer mandates.

It is imperative that the new Director leverage the Center's newly minted prestige to seed the long-term projects that, in his/her judgment, serve the Center's vision. This is the time to recruit, from outside and from on campus, the people that the Director sees as being necessary for success at the third-year milestone as well as the people that s/he sees as being vital to the long-term vision of the Center. At this early stage of the Center's development, newcomers will largely be seen as replacements for departing faculty who may not fit ideally within the CREST's vision; and the Director may find that new recruits are readily welcomed into the Center.

Different approaches to recruiting are taken, depending on the CREST and its relationships with the departments involved. But some approaches are fairly standard. Usually one of the members of the Directors' executive committee is a member of the search committee in their respective departments. Center members attend the interview seminars, meet with the candidate in one-on-one discussions, and offer comments to the search committee based upon their experiences with the candidate. The decision about areas in which faculty should be hired usually remains with the individual department heads and their faculty. However, it is vital that the Center Director, as well as the participating faculty, be actively involved in the recruitment of faculty. The success of the Center critically depends on the quality and interests of the faculty being recruited. Similarly, the Director and Center faculty must work closely with the departments involved to ensure that the individuals recruited ultimately add value to both the Center and to the department. This can be a major challenge. To make it easier, it is ideal if the Center can be proactive in strategic planning with the departments with regard to mutual opportunities and responsibilities. Center administrators should try to meet regularly with Department Chairs in order to keep lines of communication open, and should make known the Center's needs for faculty with particular qualifications.

In most cases, new faculty have an appointment in their respective departments but are committed to spend a substantial portion of their time (typically half) on Center research projects. In some Centers the CREST has taken the lead in recruiting a new faculty member, providing half a line while

the department provides the other half. This is possible, of course, only if the university has dedicated faculty positions to the CREST.

It should be noted that a CREST generally can hire professionals devoted entirely to the Center, including non-faculty research staff, without a direct appointment in an academic department. Such individuals play an essential role in the management and operation of all the CRESTs. Although this capability is valuable, it is important to realize that when the strategic plan changes, these individuals may not fit the new plan and must be reassigned or let go.

In the early part of this stage in the development of a CREST, it is essential that a certain attitude becomes embedded within the Center. Conflicts and competitions will be inevitable as long as the Center's research establishment sees the NSF grant as a pie from which each party hopes to receive a slice whose size is commensurate with his/her own perception of their talent and potential value to the Center. The Director should reinforce the attitude that the Center is in fact much more like a bakery in which participants can bake cooperatively a large variety and number of pies and thereby satisfy their research cravings, fostering the growth of the Center while serving the Center's equal interests in education and technology transfer.

A mature CREST represents an investment of $5 to $10 million in NSF funds that would otherwise probably have been spent to initiate other Centers. To be favorably evaluated at each project milestone, a mature CREST will have achieved world leadership in its chosen field of specialization. It is at this time that the Director's recruitment activities will become both more important and more difficult.

New recruiting may become more difficult because the Director can only offer Center support for tenure-track appointments in allied departments, as few academics would accept a faculty appointment exclusive to a CREST at this stage of its funding. When the university and the allied departments have formed a firm resolve to continue support for the Center's educational activities, and industry has firmly decided to continue to underwrite both education and technology transfer, very creative recruiting can continue at a brisk pace. As the Center matures, the Director may choose to recruit a fresh cadre of faculty with specific interests and talents in the area of team-oriented, industrially related, interdisciplinary education; this transition, however, cannot be abrupt but must be implemented in a smooth and steady fashion.

It is clear that the Director of a CREST is the keeper of the Center's vision and that recruiting is his/her most effective weapon in the realization of that vision. The Director will make pivotal decisions on Center administrative and research management structures, but these structures are only as good as the people that the Director can call on to staff them and make them work. If the vision articulated by the Director of a CREST inspires and sustains interest within the engineering and scientific communities, many of his/her colleagues will be interested in affiliations with the Center that may range from simple exploratory visits to total commitment.

This interest facilitates recruitment strategies that include the recruitment of established research faculty from the university itself, and the well orchestrated opening and filling of new faculty slots in areas that strengthen both the Center and the affiliated departments. Recruiting must strive for balance, as it does for excitement, and it must also serve the interests of the education and technology transfer programs that assume special importance as the Center matures and plans for its continuity.

2-16. Relationships within the University

The establishment of a CREST constitutes a major commitment on the part of both the NSF and the host university. The Center comprises a unique opportunity to reinforce a research/education/technology transfer entity within the university to the level where it becomes a world-class resource and strengthens U.S. industrial competitiveness. American universities range across a very wide spectrum in the degree to which they will really commit themselves to support individual Centers, and therefore in the degree to which they will guarantee the continuity of these exciting enterprises after NSF support is terminated. Certainly, some research-intensive engineering schools play the game of "musical Centers," in which Centers of many kinds wax and wane and no lasting changes are made in either team research or interdisciplinary education. These schools form dozens of Centers in response to changing funding opportunities, and they strip space and personnel from fading Centers very rapidly in order to initiate new revenue-generating enterprises. If the university is really committed to the objectives of the CREST Program, it will become a part of the university's own strategic plan at the level of the Provost and certainly the Dean. The university administrators will make specific long-term commitments to a new CREST in terms of both space and personnel. The university will also make significant changes in curriculum, and even in departmental structures, to nurture the Center as a

permanent part of its revitalized programs. Research alliances come and go, but a Center can become a permanent part of a university if researchers stay together because of the value added by interdisciplinary research teams and by an education predicated on cooperation between departments and in cooperation with industry.

2-17. Leveraging University Resources

Perhaps no decision that the Director of a CREST will make during his/her tenure is more important than the pivotal decision to press hard for contiguous space for the Center. Especially if the Center embraces several traditional disciplines, it is important for its faculty members and students to be housed in contiguous space in order to develop the cohesiveness that is the life blood of a CREST. Faculty members will adopt a spectrum of arrangements that mirror the extent of their commitment to the Center, in that some will have labs and offices in the Center and work exclusively with Center research teams, while others will retain offices and labs in their home departments and attend research team meetings and seminars in the Center. But the key is that all Center students will be housed in contiguous space, making the Center their home on evenings and weekends, and integrating to form informal research teams and supportive friendships that will make them profoundly different from conventionally trained students. The new CREST may be forced to be a "virtual" Center that exists in the common will of its participants and in the vision of its Director, but whose physical being is a distributed network of offices, laboratories, and personnel connected by electronic linkages. It is essential to ensure that all CREST students understand clearly the mission and goals of the Center and how they relate to the way things are done in the Center. This is important not only for the students but also for the Center itself. Nothing is more deadly than the perception by a site visit team that the students have no idea what the Center is all about.

2-18. Relationships Within the University Hierarchy

In any major university, the senior administration is confronted almost daily with demands for support of specific programs by forceful proponents. The Director of a new CREST must present his/her vision of the Center persuasively enough that the Dean and the university's Provost and Vice-President for Research, who are rarely both engineers or even scientists, buy into the vision to the exclusion of distracting demands. The concept of the

CREST is inherently exciting, and the objectives of a CREST are unique, but the Center will not thrive if it does not capture the strong support and commitment of the university's senior administration.

To engender that support, it is imperative that the CREST be recognized throughout the university community as being on a plane of intellectual and scholastic excellence that equals or exceeds any other research unit at the university. Even 10 years after it is established, the Center's accomplishments in research and education should loom large in the university's own public assessment of its strengths. If the CREST does not dominate the internal priorities and self-image of the university, no amount of NSF planning and/or support will guarantee its continuity as an effective unit when it "graduates" from NSF support.

The Dean of Engineering must be willing to commit space and faculty slots to the nascent Center. This individual in particular must be a dedicated supporter of the Center. The Dean can be invaluable to the CREST and its Director as a facilitator, a "fixer," and an all-around strengthener of the Center within the university. To that end, the Director should not hold be aloof from such college functions as Parent's Day or alumni functions, because loyalties and goodwill are bidirectional.

The Provost and the Dean of Graduate Studies should be proactive in support of the acceptability of thesis work done on Center research terms. The Vice-President for Research should help in the acquisition of contiguous space for the Center, and he/she should support the Center financially by helping to secure state funding and by returning a proportion of the indirect costs (IDCs) on Center grants. Eventually, the Vice-President for Research should be so impressed by the Center's success in team research, interdisciplinary education, and technology transfer that he/she will be willing to commit significant portions of his/her disposable income to the establishment of additional *de facto* Centers.

2-19. Relationships with University Departments

The Director of a CREST must realize that the departments are the continuing administrative entities of the university. Most Center faculty will hold tenured or tenure-track positions in conventional departments, and virtually all graduate students will actually be registered in these departments. (Indeed, the support that departments provide to a CREST often appears to be roughly proportional to the number of their faculty and students that it

supports.) Departments offer Center-specific courses and share in the costs of equipment. A Center cannot succeed without the support of departments, but it is a difficult relationship that must constantly be nurtured. Department Heads come and go, but the CREST Director must continuously persuade the power brokers of key departments that the Center enlarges their research horizons and enhances their students' education.

What is really needed is very strong leadership from the Dean (and higher university administrators) to make everyone involved understand that working in a positive manner with the Center is in the interest of the departments. In particularly enlightened departments, the Center Director may even receive kudos for effective contacts with industry.

Many of the real problems that will challenge a CREST Director will involve affiliated departments directly, and the Director simply cannot afford to ignore this critical academic interface. Some departments will be only distantly related to the Center, but normally two to six will be intimately involved. Divisive issues will include department faculty who "disappear" into the Center and then expect recognition within the department for CREST-related accomplishments that most department faculty may not even know about. Similarly, in some cases there may be graduate students who are recruited by the department and then disappear into the Center space and Center activities, only to reappear three to four years later expecting an advanced graduate degree from their "home department." CRESTs are powerful, in terms of funding and the inherent appeal of their vision, and they can engender resentments in allied departments that may surface and confront the unwary CREST Director when s/he least expects it.

Regular meetings with the heads of affiliated departments can help both parties to identify faculty and student problems before they become too serious. Faculty slots that are allocated to the CREST should be filled in a way that benefits both the Center and the department concerned. The Director should work with the departments to ensure that the filling of these slots not only benefits the Center, but also contributes to the long-term interests of the department. The CREST Director should apprise the Department Head of plans for increased research activity that will draw specific faculty away from teaching responsibilities, so that alternate plans can be made in a timely fashion. There is no reason why a Department Head should be alerted at the last minute about demands for either "teaching relief" or other special concessions related to the research activities of CREST-related faculty. The CREST Director should submit a written

assessment of the performance of each faculty member to his/her Department Head, in ample time for its inclusion in the department's annual report.

The issue of promotion and tenure deserves special attention. Promotion and tenure decisions are made in the departments, and any animosity felt toward the CREST can easily be objectified in adverse promotion and tenure decisions regarding Center junior faculty. In addition, the possible adverse evaluation of team research and multi-authored papers has been a point of uncertainty for many faculty and students considering participation in a CREST. In most cases, there is considerable collegial interaction on these matters between the departments and the Center. Generally, the Director and/or senior Center faculty provide departments with letters of assessment and/or support for candidates. In many cases, senior Center faculty hold positions on the departmental review committees and college committees, where they have the same privileges as faculty from the departments. In certain instances, it is reported, the input of the Center Director has been the deciding factor in a positive promotion outcome. More than one Director related that participation in the Center is viewed as favorable, not unfavorable, for promotion and tenure. Even in the few cases where the Center has no direct influence on departmental and college review committees, the outcomes have been favorable.

The CREST should cooperate with allied departments in the recruitment of graduate students, and the CREST Director should pay special attention to the composition of the advisory committee for Center graduate students. In the simplest case, the student's thesis advisor will be a member of his/her host department and other members of the advisory committee will also belong to that department. In other cases, an advisor from outside his/her home department may supervise a graduate student and the advisory committee may be of mixed composition. Especially in this latter case, it may be important to have the student give regular seminars in the home department, in addition to Center seminars (they require no additional preparation), so that departmental people are not blind-sided by the final thesis. If the vision of the CREST is truly innovative and really addresses the cutting edge in the field, the student's thesis may well seem like fantasy or heresy to members of the home department, and departmental faculty should have adequate opportunity to get used to these new concepts.

Good relationships with allied university departments should be effortless and natural, and they are vital in the solution of many of the problems noted by

Directors (such as faculty recognition and student integration). For example, attending meetings of Department Heads called by the Dean may strike the new CREST Director as a waste of time, because many issues may not really involve the Center. However, regular attendance builds good relationships and common interests and reassures the Dean and the Department Heads that the talented Director of this new research unit, the CREST, is just another member, like themselves, of the university leadership community.

2-20. The Strategic Relationship With Industry

One of the first lessons that a new Director learns, as s/he begins to get involved in technology transfer, is that there is a spectrum of different forms of potential interaction between any company and any academic entity. In the most academic form, the most research-oriented of the company's employees will attend IAB meetings to hear papers and see posters in the best academic tradition, much as they would attend meetings of the learned societies to which they belong. These people and their research units are often overworked or understaffed. They will persuade their companies to seek short-term, highly focused assistance from the Center for small projects, assuming that his or her corporate-level managers can justify the annual expenses of membership and travel. Experience indicates that there will always be a high rate of turnover of these more "academic" relationships.

The next level of relationship commonly found in CRESTs begins to involve the upper-level managers who are responsible for research management and strategic planning in their companies. When they come to respect the technology transfer capabilities of the Center, they often will propose joint research projects that may be funded by themselves, by a consortium of companies in that area, or by a third party (commonly a federal mission agency). These contracts are very lucrative; often they mesh well with the strategic plan of the Center; and they cement the relationship between the Center and the cooperative company or companies. These cooperative contracts allow the sponsoring company to see the Center and its students in a very positive light and, especially if students have been specifically mentored by the company or placed in industrial internships, the company often will hire Center students.

The close interactions of CRESTs with their industry technical advisory committees have not only been highly effective in guiding the Centers' plans

and research; they also have taught the need for flexibility in interactions with industry. Industry doesn't speak with one voice; each company has different needs and priorities. Persuading industry personnel to visit a CREST even briefly (e.g., for one-day seminar visits) invariably brings surprised and highly positive reactions to what the Center is accomplishing. It is essential that both parties have realistic expectations concerning the prospective interaction, in order to avoid disappointment.

2-21. Outreach to Other Institutions

Outreach to other institutions for research and education is one of the goals of the CREST Program, which hopes by this means to disseminate more rapidly and widely the "CREST culture." It is accomplished through a variety of mechanisms, including joint proposals, exchange of faculty and/or students, direct funding for specific research tasks, consulting activities, and other means. The goal is worthy, and in fact the results of these interactions have largely been worthwhile. However, some lessons have been learned in the course of pursuing them.

First, it is essential to identify concrete reasons for pursuing an outreach activity with another institution. Successful alliances can be established only when both parties benefit from the collaboration. Second, it is necessary to identify those institutions that have capabilities and facilities that are complementary to the CREST's. In this way the interaction becomes a win-win collaboration that benefits both sides. Third, discussion among the CREST thrust area leaders should identify the appropriate individual to contact at the other institution. The approach is then made and, if there is an interest, joint discussions are held to ensure that the outreach institution participant(s) have the same goals and are willing to follow the procedures used in the CREST. It is important to ensure that there is a strong intellectual match-up. Experience demonstrates that financial support alone is not a sufficient basis for a strong partnership.

It must be realized that failures can occur. Therefore, it should be made clear at the outset that, if the interaction is not successful, the alliance will be terminated.

2-22. Life After NSF

The immediate success of a new or prospective CREST depends heavily on the extent to which the Director's vision engages the CREST's team, the university, and industry and also satisfies the NSF Directorate and its site visitors. The short-range continuity of a CREST depends equally heavily on the Director's success in continuously revitalizing the Center through the real integration of new faculty from within and outside the university. The long-range success of the Center will depend entirely on the extent to which the continuing partners--the university and industry--value what the Center has accomplished in interdisciplinary education and team-based research.

The long-range continuity of a CREST, which is NSF's objective for each CREST, depends on effecting a cultural and structural change in the university and a real and mutual interdependence with industry. Perhaps a CREST Director is best evaluated on the extent to which s/he has really embedded the Center into the functional fabric of the university and into the machinery and the bottom line of industry.

The Center's relationship with industry is an equally important component in its long-range continuity, and in its effectiveness in giving substance to its vision. Today's "leaner" companies cannot afford large, esoteric and unfocused research groups—any more than they can afford to send their people to yet another set of dry academic seminars. However, the fact remains that most of the groundbreaking research on which modern industries are based was and is conducted in universities. The CREST that successfully makes the connection between university-based research and real industrial needs may outlive most of its faculty. A strong CREST will spin off ventures with a real chance for survival and/or it will integrate itself into the planning process of companies to form functional strategic partnerships. The Director and the CREST team must have built a broader and deeper contact with industry, one that is fully and functionally connected to the Center's education program, if the CREST is to rely on the not-inconsiderable financial resources of industry to ensure the Center's long-range continuity.

Education and technology transfer both are inherently long-range undertakings, and they are optimally combined in the CREST program mandates. Many of the CRESTs already are valued very highly by industry because they focus university research at a point where industry can grasp and exploit it, and because they produce a steady steam of uniquely cross-trained, team-oriented graduates who are likely to eclipse their peers in creativity and productivity. There is enough potential at the industrial

interface to "power" a Center indefinitely, and without NSF funding, but the Director must harness the educational support of the university to preserve the essential strengths and distinctions of a CREST.

The key to surviving and thriving after NSF funding ceases may well be to begin planning early--ideally in Years 2,3 and4—for self-sufficiency. In order to continue the type of culture that the CREST has engendered, it will be necessary to maintain at least the essential elements of the Center's infrastructure. As funding tightens, the "refinements"—features such as services (e.g., analysis and demonstrations), shared facilities upkeep, education programs, seminars, etc., that help define the special nature of a CREST—will come under scrutiny as luxuries. Some form of these infrastructure elements will need to be adopted and perpetuated by the university (not industry, as this is part of the university's mission).

There are at least three issues that need to be resolved before a CREST graduates from NSF funding to self-sufficiency. These issues include: funding, space and administrative position. In the best of cases, it may take a year or more to negotiate a permanent position for a CREST in the permanent university structure. Since resources may be controlled by several different levels in the university (e.g., the Dean and upper administration), there are several negotiations that must successfully be navigated. In addition, with the tendency for shrinking average time in office (it has been noted that the average time in office of a university president today is about five years), chances are the initial agreement may have to be renegotiated one or two times before a stable, long-term agreement is reached. The CREST requires a plan and positive leadership during this period to maintain high morale with the Center faculty moving forward together. Whatever the agreement, get the arrangements in writing. Verbal agreements are easily misunderstood.

Funding—Universities have different ways of creating discretionary funds. These include return on overhead; interest on money in university accounts; and return on tuition, gifts, and income from technology licenses. If given a formula, the CREST can directly influence the income from the first three sources by generating more contracts, banking more discretionary funds and admitting more students. On these first three, projections can be made and a budget established accurate enough for planning purposes. The latter two categories should not be depended upon for on-going operational expenses. Many universities are familiar with the departmental structure, which is essentially a "no growth" or "slow growth" organization. Budgets may be

fixed more or less from year to year. It is important for CRESTs to have an incentive-based funding. They need to provide equipment and infrastructure for new projects and new domains. They need to generate seed funding to start new ideas that can eventually mature into self-sustaining multidisciplinary research projects. Yet another issue is "who gets credit" for bringing in the funding. As a multidisciplinary research Center with faculty from Engineering and other departments, there should be no tension in determining which department a faculty member initiates a research proposal through. A simple rule applied at some Centers is that if the proposal has faculty from multiple departments as Principal Investigators who are part of the CREST, then the CREST is the appropriate organization to receive credit for that proposal.

Space—The first issue is to guarantee that the space the Center currently occupies will remain its own. Since space planning often occurs five or more years prior to physical occupancy, it is important for CRESTs to understand what will happen with their space once they transition. In addition, the CREST needs to determine the space allocation process so that new space can be acquired as the CREST grows.

Administration—It is important to establish where in the university hierarchy the CREST Director will continue to report. This has a direct impact on strategic planning and promotion of Center personnel. It is important that Center personnel sit on both the faculty and administration promotion committees to represent the unique perspective of multidisciplinary research. Center Directors can educate their colleagues on these committees as well as ensure steady advancement for personnel involved in the CREST. In addition, the CREST should be an integral part of the administrative strategic planning process, not only to ensure stability for the CREST but also to inject new perspectives into the strategic planning process.

It is crucial to begin early building a case for this eventuality within the university. All participants in the Center, not just the Director, should be involved. The industrial liaison specialist should become involved with the university's technology transfer people by sharing information, experience, and resources. There are many ways that the education coordinator could share resources with the existing units on campus and make it known. The AD continuously works as a liaison with the university's administrative network and, while constantly compromising to accomplish things, is able to air the Center's perspective. If the Center has found a better way to do something, share it. At every opportunity, Center participants should get

others within the university on their side so they would be missed if they weren't there. Everyone has a chance to make himself or herself indispensable by becoming actively involved in campus activities. Always think beyond the Center!

The university has to be reminded constantly of what the Center is accomplishing, with the emphasis being on *why* it is important. Sell the ideal, not the Center. (For example, emphasize that Center graduates are very employable because they have interdisciplinary training and can work in teams.) Centers gather a lot of data; probably no other unit on campus has as much tracking information as the CREST does. Share these statistics with the university early and often; the university may become dependent upon it and want to maintain the Center's infrastructure partly in order to continue gathering it.

Again, the concept is that of marketing the ideals upon which the Center is founded, as opposed to marketing the Center itself. If the culture of a particular Center becomes too closely identified with the NSF CREST program, it will die when the NSF funding stops. Therefore the real challenge is to create and continuously showcase a set of values that will be embraced by the Center's continuing partners. A Center might consider creating a position for a marketing manager. In the short term, these individuals would market the Center itself (through publicity, contacts, recruitment, etc.). But for the long term they would market the ideals and identify opportunities to illustrate how the Center has served as a demonstration vehicle to accomplish those ideals and how the university could build upon that experience.

2-23. Summary

The job of directing a CREST is all about choices. No one should choose this powerful and prestigious position if he or she is not fully committed to the stated objectives of the CREST Program and to its values of team-oriented, industrially relevant, interdisciplinary research. The Director of a new CREST must choose the extent to which he or she will delegate and the areas over which s/he will retain effective control. Choices also are implicit in the assembly of the team that will apply for the CREST, and of the teams that will run the Center at all stages of its development. A balance of research talent and commitment to the Center's vision is essential, and interdisciplinary education and technology transfer will not reach their full

potential unless the Director chooses his/her teams wisely. It is naive to expect that every Center faculty member will excel in all Center activities, but a subset must be capable of world-class work in each of the major areas of research, education, and technology transfer.

Within the university framework, a CREST Director must choose his/her style of interaction. A measure of persuasion and firmness may be necessary to obtain contiguous space, at the outset, and to take full advantage of the university's pledges of support for the Center. As the Center matures and begins to concentrate on the continuity of its research, education, and technology transfer programs, cooperative relationships with allied departments and the appropriate parts of the university hierarchy come to the fore. Mutually beneficial recruitment is the Director's most potent asset in this matter and a confrontational approach by a mature Center may leave it surrounded by enemies at a time when it most needs friends. It is the stated intent of the CREST Program that the Centers should make lasting changes in university education and also sharply improve the competitiveness of American industry; and most CRESTs actually accomplish these objectives. Clever recruitment and excellent relationships within the university can extrapolate these changes by passing the Center's vision to the university departments and faculties that constitute the operative research-education-technology transfer mechanism of our university system.

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CREST Best Practices Manual
Chapter 3: Research Management

Contents

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EDITOR'S NOTE—this chapter is taken nearly verbatim from the Engineering Research Centers' Best Practices Web site (online at http://www.erc-assoc.org/manual/bp_index.htm), which may be consulted to compare and contrast with the CREST practices detailed below.

3-01. Introduction

The objective of this chapter is to describe methods for carrying out strategic research planning and its implementation. The interface between research and other CREST components—such as education and outreach—and the impact assessment of CREST outcomes are also covered, and the challenges and rewards of research in a cross-disciplinary environment are also summarized.

3-02. Strategic Research Planning

The core of the CREST's strategic plan is its research strategy. Strategic research planning is generally a systematic, stepwise process, as described below.

State-of-the-Art Analysis—The first step in developing a CREST research strategy should be to conduct an analysis of the state of the art in the field. An understanding of the state-of-the-art underlies the development of a Center's vision of achieving major advances in a given area of science, technology, engineering and mathematics (STEM). This understanding aids in identifying the barriers that stand in the way of further progress, culminating in a set of research objectives that, if met, move the Center toward achieving its vision. As the Center progresses, the state-of-the-art analysis should be continually updated, tracing the development of the work in fields closely aligned with the Center's vision and documenting the contributions made by the CREST's faculty and others around the world. This documentation provides the Center with a history of its contributions, and those of others, to the field.

Vision—Just as a well-thought-out research strategy is essential for effective research management, a compelling and well-articulated vision of the Center's purpose and advances to be achieved is the key to a compelling research strategy. The vision should motivate and encourage participation and interest in the Center and its activities, aid in recruiting faculty and industry to become involved in the Center's research agenda, and attract industry and government support. It is important to have the broadest possible understanding and acceptance of the vision among CREST

participants. Without this, it will be difficult to keep the research integrated and focused on achieving the goals of the Center. It is essential that all participants understand the vision, why it is important, and the means the Center plans to employ to achieve the vision. The steps required to achieve the vision and how these steps will be undertaken should then be articulated in the strategic plan.

Usually it is the Director who recruits research faculty and staff who have expertise in a particular area considered to be essential for achieving the Center's vision. The challenge is in formulating a shared vision that balances "top down" management with "bottom up" faculty expertise. The Director is responsible for putting in place a process for formulating the Center's shared vision. If this is skillfully done, faculty should take part in contributing to an achievable vision, developed through a logical, participatory process, not one mandated from above.

Identification of Technical Barriers—Management articulation of the technical barriers is essential in carrying out a successful research strategy. Otherwise, the Center faculty could easily work on solving problems that may be of interest to them but that would not lead the Center toward achieving its vision. No matter the reason for the choice of problems to tackle, the Center should make it clear to all participants why the technical barriers it chose to address were selected. This will help in further elucidating, to those inside and also outside of the Center, the strategy the Center plans to follow in achieving its vision.

A Center must also identify broader barriers to success that are not strictly technical, such as costs, policies, and regulations. In some fields, industry is in an excellent position to thoroughly appreciate these issues. They develop products for various applications and understand the forces that may prevent their products from being accepted in the marketplace. One forum for identifying barrier issues is at a strategic planning meeting that includes industrial representatives, where technical discussion sessions focused on barrier issue identification may be held among faculty, students, and industrial colleagues.

The Research Strategy—The research areas on which the Center has chosen to focus in order to achieve its vision should follow from its understanding of the state of the art and identification of the technical and system-level barriers yet to be overcome. The heart of a Center's strategy is how its research is brought to bear on these barriers, which cannot be overcome without the integration of interrelated research activities.

The research strategy should identify what breakthroughs or developments in fundamental science and/or enabling technology are required initially, how they are interconnected, how further progress will build on these achievements and contribute to a convergence on the systems level, and which projects can and should proceed in parallel.

Goals and Objectives—In organizing its research strategy, a Center should formulate major goals that must be met as a demonstration of progress toward achieving its vision. The formulation of clear-cut goals will aid in defining a pathway toward major accomplishments, along with the outcomes expected from specific projects or research areas.

As a Center strives to meet its longer-term goals, objectives should be specified in the strategic plan that brings to a culmination parts of many individual projects.

Deliverables—The ability of the CREST to achieve industrial use of its knowledge and technology is a key element of a successful CREST, one that requires a strong partnership with industry. Deliverables can take many forms, including fundamental knowledge advances and discoveries, new theories or models describing physical properties or behavior, access to students, experimental techniques, software, and new materials and processes. The opportunities to develop these deliverables, and their possible utility to the industrial partners, should be recognized and considered during the development of the research strategy. Deliverables may stem from research at all levels of investigation, ranging from basic science to engineering testbeds. It should be noted that how a deliverable can best be understood and incorporated into a company's workflow is not necessarily straightforward, as students and faculty may have different expectations from those in industry regarding the utility and user-friendliness of the tools they develop.

Testbeds—The key to determining if the Center's research agenda will successfully lead to a next-generation engineered system and achievement of the Center's vision is to periodically pull together the research outcomes and test the system. Thus, the research strategy must involve the development of proof-of-concept testbeds, which integrate elements of the system to determine if all components work together as planned. These testbeds not only ensure that the research outcomes are integrated and tested, they also serve to drive the research. They act as focal points for the researchers when planning their research projects. They also supply a framework for faculty, students, and industry representatives to work together and to gain a better understanding of the system *in toto*. Perhaps

most importantly, testbeds highlight which areas of the Center's research require further investigation, ensuring that the research is focusing on the critical problems that must be addressed in order to achieve the Center's vision. Thus, testbeds facilitate modification of the Center's research strategy based on what is being learned as the Center works toward achieving its vision.

3-03. Achieving Participant Buy-in

Faculty Buy-in—When putting together a research strategy and agenda, both the research required to achieve the vision and the research interests of the faculty must be taken into account. If there is not a good intersection of the two, it will be difficult to recruit enthusiastic researchers to the Center. Also, in the academic setting, a directive "command approach" generally does not succeed in motivating faculty. A Center is most likely to reach its goals if all participants feel a sense of ownership of the research strategy. CREST research managers have found that it is very important to obtain agreement to the research strategy of the whole CREST team up front. Trying to achieve consensus later on is impossible unless there is agreement at the outset.

Obtaining and maintaining faculty buy-in to the strategic research plan are not the same thing. Centers often encounter the problem that, once they have agreed to a strategic plan, faculty members are obliged to modify their own personal research objectives to an extent. Some will try to weave their own research into the Center's agenda whenever possible. The faculty cannot do this as objectively as the Director can, and some will resist making major changes in the direction of their research. There must be at least a critical core of faculty who are flexible enough to adapt to changing needs.

The full range of research expertise required throughout the lifetime of the Center as it works to achieve the vision may not be resident at the university at which the Center is based, nor at any of its partner universities. The need for additional expertise, when it exists, must be recognized and filled by means of outreach to researchers at other institutions. Normally these would be paid research projects; continued involvement of these faculty in the CREST would depend on the quality of their work and its continued relevance to the CREST's needs.

Industry Buy-in—A key element in building a strong industry partnership is to actively involve industry in the strategic planning process. Both the creation and evolution of a CREST and its strategic plan must involve frequent input from the industrial members. Most CRESTs have constructed formal

mechanisms through which to continually draw upon industry's advice and experience in technology development. These mechanisms are described in detail in Chapter 5.

A Center must strive to develop with its industrial supporters a rapport where each recognizes its role in the CREST technology development philosophy. Industry's role is to present the CREST with "model systems" or realistic conditions, so that the CREST's fundamental research has pertinence. Industry should realize that the time horizon for most technology development in academic basic research is 5 to 10 years, while in industry it may be measured in months. Again, each CREST must build infrastructures or mechanisms to draw industry into the active role of taking discoveries and creating technologies. It is in these joint activities that the CREST and its industry members begin not only to solve problems jointly but also to create new technologies.

3-04. Implementation of the Research Plan

Management of a complex research strategy involving multiple teams, multiple team members, and varying objectives and goals is difficult at best. While the strategic plan sets out a unifying vision of what is to be accomplished and establishes overall Center research goals and objectives, ultimate success for the entire undertaking requires the establishment and integration of project goals and objectives, including the proper prioritization of time, effort, and resources to be applied to each. This level of research management requires that each project or groups of projects include firm estimates of the resources required to address the project (including people, money, and equipment) in the time given to complete the project.

It is important to realize that research management is not a smooth process. It involves continuous experimentation. The optimum management approach is different for every Center, and also will change over time.

CREST Research Management Team—The research management team at an CREST may consist of a varying number of individuals in different functions, depending on the Center. At a minimum, the Center Director holds ultimate responsibility for the planning and direction of the overall research program, with a faculty member designated as the leader of each research area.

Many CREST also have an executive group, often called the Research Review Committee, that meets periodically to review and assess progress in the Center's research areas, select projects, allocate and adjust research funding, and make adjustments to the Center's strategic plan as necessary.

This committee typically consists of the Center Director, possibly the Deputy Director, the Associate Director for Research (if applicable), research area leaders, and one or more representatives from the Center's industrial members—or some combination thereof.

Initial Implementation Steps—In establishing the resources required to complete the research, the relative priorities among intersecting projects must be established, assuring that those projects that must be completed or substantially completed before other work can progress are recognized in advance. The research team must set priorities among and between projects that compete for resources and must set deadlines for deliverables from each project. These actions most often require the creation of a research review committee or some other organizational management entity charged with overseeing the research plan. Some thought will be required as to how deliverables from each project or set of projects will be communicated to other teams and team leaders as well as to industrial advisory boards.

Defining timetables and milestones for basic research can be both subjective and contentious. Being too specific tends to restrict the Center's creativity in pursuing its goals. To get around this difficulty, it is a good idea to develop broad objectives for basic research and review the objectives periodically throughout the year.

It is necessary to establish a finite duration of projects—not much longer than 1 to 2 years in most cases. Management of the research program should take into consideration the objectives of other program elements of the CREST, particularly education. Processes should be established and exercised to ensure frequent faculty/student interaction across the disciplines or research teams. Involving the students in this activity is one of the most important contributions a CREST can make to STEM, as it helps in creating a competent, cross-disciplinary work force capable of working on difficult problems in industry and academe across disciplinary boundaries. Similarly, involvement of experienced students in research management team meetings strengthens the CREST and helps prepare students better for the future.

Updates and Revisions to the Research Plan—Research managers must establish and exercise processes to revisit and revise the research strategic plan regularly, incorporating progress in research efforts as goals are achieved. The plan is only as good as the benchmarks it sets, so in order to be a useful tool, it must be modified as progress is made or as the overall Center strategy changes. The plan helps keep the entire effort on track and communicates the progress and timeline to all members of the team. It is

useful to establish a method for frequent exchange of information—on a Web site for example—where basic assumptions about the plan can be seen by everyone. A time should be set for a regular brief review of the plan by the entire team. The outcome of this review might include new time schedules, integration of activities, or new goals and objectives discovered as a result of ongoing work.

Research managers also must establish and exercise processes to determine which projects to terminate and which to add. Within the competing demands of a strategic plan, it is important to regularly review the steps being taken to achieve the Center's goals and their relative priority. To preserve valuable resources and enhance the productivity of the Center, it may be necessary to terminate projects that once seemed important in isolation or in relation to other facets of the effort, but that upon reflection appear to be unrealistic or non-viable. Projects may also be terminated if they have not progressed as planned or expected. On the other hand, in the regular review of the strategic direction of the Center and its goals, it is equally important to launch new efforts as soon as they are discovered to be potentially vital to the achievement of the goals and objectives of other projects or the overall goals of the Center. The main criterion for selection or deselection should be "Is the project on the CREST's critical path?" That is, does the project contribute directly toward the achievement of one or more of the milestones?

In developing and using a research plan, managers should use charts and graphs or other visual means and a database to track progress and document plans for future directions. A simple spreadsheet can be used to display the current state of all elements of the research program. In each of the activities above, illustration by means of flow charts, graphs, and databases may enhance the message. Illustrations also serve as a reminder of significant milestones, both positive and those that have been discarded. They will serve to link all of the members of the team together—including faculty, staff, students, and affiliated sites and individuals—giving each a stake in the efforts of the Center.

3-05. Management of Research Funds

Funds received from NSF for a CREST are meant to create an academic infrastructure that will enable the Center to produce world-class research, facilitate industrial/academic research cooperation, create a new level of technology, and devise innovations in STEM education.

Financial Oversight—In some CRESTs, financial management and oversight of funds allocated to the research program may be within the province of the Center management or administrative staff. Some CRESTs involve STEM faculty in financial oversight or planning committees that are responsible for making short- and long-term spending decisions, while the CREST financial manager tracks finances, grants and contracts, and daily expenditures.

Regardless of support received from the host institution's Grants & Contracts or Sponsored Programs Office, it is a good idea for a CREST to establish its own independent electronic accounting system. If possible, the accounts administrator should provide a numerical account code system that provides each research and education activity with its own operating budget.

Use of Internal CREST Funds—How a CREST initially negotiates resource returns to the Center varies across institutions. Such decisions, often not made solely by CREST management, have a direct impact on resources available for CREST activities. It is critical for CREST management to negotiate up front (i.e., at proposal submission time) what the arrangement will be for IDC recovery, matching, etc.

Given some rough idea of the income available to the research program, decisions must be made as to how to dispense these resources among the many research areas and industrial activities. Each CREST has its own policy regarding the cessation of CREST support and the termination of a project. PIs should be given enough notice of the termination of CREST funds to allow them to secure other sources of support. In this regard, if all projects (and possibly even research areas) are made aware that support is of finite duration and based upon clearly stated performance criteria, then the need to seek external support should be a constant goal, not an unexpected surprise.

Each CREST should plan how it intends to involve industry financially in the task of taking CREST discoveries and transferring them to new technologies. Industrial membership in a CREST can cost a few thousand to several hundred thousand dollars in fees.

In summary, CRESTs must plan at an early stage those "uninteresting" but critically necessary mechanisms for distributing research support, evaluating research success, and promoting the continual efforts by all to secure external research support.

Industrial Collaboration and Technology Transfer—CREST research programs are designed and managed with the continual involvement of industry. All CRESTs have involved their industrial member companies directly in the

establishment and refinement of their strategic plan. Some CRESTs align industrial representatives with specific projects within a research area in a way that provides both CREST students and faculty with a continuous industrial perspective on the fundamental research. Many CRESTs develop joint projects, in which personnel from a firm or a consortium of firms work alongside the CRESTs students and faculty on the project. This involvement creates a climate, within the CREST, in which industry not only participates on specific projects they subsidize but also has direct input into the evaluation of the research conducted.

Mechanisms to involve industry should not be confined to just the research program; to be truly successful, CRESTs must also strive to draw industry into the Center's education program. One successful method is the alignment of each CREST graduate student with an industrial "mentor" who periodically reviews the student's progress, perhaps during the annual industrial meetings, and periodically discusses the project with the student, either by telephone or by electronic mail. Formal programs can provide for graduate student internships in industrial labs during a summer hiatus. The most effective way to transfer technology is to have that student spend a few months in the company's facilities, working with industrial personnel. Hiring CREST graduates is probably the single best way for a company to absorb the broader range of knowledge inherent in a CREST; and it tends to bind the company even closer to the Center. In several cases, a former CREST student has become the company's representative to the Center. In many CRESTs, industry participates throughout the technology development process; it is a process of "mutual development." The CREST takes the process as far as is necessary to effect a successful handoff to industry. As one Center Director says, "It's a question of how far we have to carry it before they become believers."

3-06. Research Interface with Other CREST Programs

Management of a CREST's research program is best carried out in conjunction with interaction at all levels with the other components of a CREST. It is tempting to segregate the management of a CREST program along the lines of sections in an annual report, but such compartmentalization does not lead to a true systems approach. Those CRESTs that obtain recognition for their various programs and succeed in NSF reviews have not designed each component in isolation from the others. Rather, significant accomplishments are more likely to emerge from a concerted effort to intertwine the management of all CREST components.

3-07. Education

Graduate Education—Education of a new generation of engineers and scientists is the shared mission of all CRESTs. CREST education programs serve the following pragmatic roles: (1) to bring undergraduate, graduate, and postgraduate students into the Center; (2) to maintain harmony among the diverse curriculum requirements placed on CREST-sponsored students; (3) to develop new graduate and undergraduate education vehicles that go beyond traditional engineering educational approaches; and (4) to actively engage academic and industrial researchers with students on teams directed to solve problems pertinent to industry.

Research program management is implicitly connected to the education programs in all CRESTs. Research activities are driven by faculty ideas and student manpower. The attraction and retention of superior graduate students is critically necessary to the success of any CREST. How a CREST actually carries out this activity depends upon the relationship of the CREST to a host department or college (if that is the case), the degree to which the CREST research spans different colleges, and how the CREST financially supports research projects.

Certain CRESTs satisfy their strategic plan by creating team research projects that require a collection of students from different disciplines. This mandates that the CREST education program, in direct communication with the research program, satisfies specific demands for graduate students of different backgrounds. A CREST education program in such a Center can identify potential candidates by interfacing with the graduate advisor in departments around their university and also by maintaining an active CREST recruitment activity. Such an approach has the advantage of specifically identifying student expertise for each project; but the disadvantage is in the resource costs associated with independent recruiting and admissions efforts.

As CRESTs near the end of their life cycle and begin planning for potential phase-out of CREST funds, a number of Centers have elected to reduce their NSF budget direct cost requests for graduate student funds. Some senior CRESTs mandate that they will support only non-personnel-related costs of a project. Other CRESTs have elected to operate research programs in their final years utilizing Master's and postdoctoral researchers, rather than Ph.D. students, who require longer-term commitments.

Undergraduate Education—Undergraduate involvement in research is one of the cornerstones of the CREST concept. Since the early 1990s, NSF has

increased its emphasis on the impact of CRESTs on undergraduate education; a variety of programs now provide supplemental funding for CREST educational activities for undergraduates (see Chapter 4). Some students come to the Center through undergraduate courses the CREST faculty teach in the academic departments. Often, undergraduates simply come to the Center and ask for employment and/or to work on research projects.

Most CRESTs practice similar programs that immerse their STEM undergraduates directly into ongoing research projects. NSF emphasizes the development of teams in which undergraduate students work closely with graduate students, technicians, postdoctoral students, faculty, and industrial scientists on active research projects. Such undergraduates may receive academic credit, credit toward graduation with honors, or may simply receive financial remuneration for their efforts. The educational vehicles can be quite standard, such as placing an undergraduate honors student on a team research project, a graduating senior's thesis project, or a capstone design project. In such cases, the research program is not designed solely for the undergraduate experience; rather, the education program avails itself of the opportunity to expose undergraduates to real academic research.

3-08. Knowledge Transfer/Outreach

Knowledge transfer is an umbrella term for outreach activities that transfer CREST-generated research discoveries or educational innovations to the academic scientific and engineering communities. Knowledge transfer activities comprise dissemination of basic CREST discoveries and educational opportunities to other researchers and students in the field through mechanisms such as the following: visiting graduate student/faculty research exchanges, subcontracts to outside universities for specific collaborative research projects, administering summer research experiences for undergraduates (REU) programs, generation of interactive or passive educational vehicles (e.g., textbooks, interactive CD teaching modules, computer-aided design programs, video tutorials, and Internet homepages), and CREST faculty service to professional societies in staging national and international symposia.

The focus of all CREST knowledge transfer/outreach activities is both educational and technical, but the emphasis varies greatly across activities. At one extreme, undergraduate REU programs emphasize primarily the exposure of students from other institutions to CREST research as an educational mechanism; the purely technical value beyond education is

limited. At the other end of the spectrum, faculty exchanges or visits are aimed primarily at maximizing the flow of knowledge between researchers from different universities; here, the educational value is secondary, although it becomes quite significant when the visiting faculty member returns to the home institution. Most outreach activities involve a more balanced mix of knowledge/technology transfer with educational value. It is a characteristic of CRESTs that the two are never entirely inseparable and are often fully intertwined.

3-09. Overall Impact Assessment

Intellectual/Academic Advancements and Achievements—From a research standpoint, the impact of a CREST is measured through its industrial interaction and knowledge/technology transfer successes, along with traditional academic measures such as published papers, patents, software products published, students graduated, etc. Thus, some yardsticks are more tangible and objective than others are.

The emergence of a Center as a recognized national resource in its field is a strong indicator of its impact. A number of CRESTs have become firmly established as national resources. Start-up companies often are spun off by CRESTs, based on enter-developed technologies and usually with CREST graduates and faculty members as principals. Positive impact is apparent if Center faculty are often invited to present papers at major professional symposia in their fields. The formation of large industrial consortia around the CREST, the operation of unique testbeds and testing/simulation facilities that are heavily used by industry, and the hosting of well-attended international conferences all provide tangible indications of this status.

Perhaps the greatest measurement of success, however, is articulating an original vision far ahead of the university community or the industrial sector in specific areas of research, to which the rest of the community is gradually converted as the accuracy of that vision is demonstrated over time

3-10. Cross-Disciplinary Research In A Disciplinary Environment: Challenges and Rewards

One of the first challenges that a CREST Director, or prospective director, faces is to oversee the collective planning of a long-term research strategy by a group of people from different disciplines, many of them already quite successful in their individual research programs, who may not have even worked together before. The reward, for the research manager, is in being

able to persuade the members of such a group to aim their research in a direction they may not have wanted to go and may not initially have understood—and then to see them arrive at the recognition that the Center's vision is valid and that they can succeed in the context of the strategic plan.

It is certainly challenging for a group of disparate faculty members collectively to determine where the "uncharted territories" lie in a given field, especially when the field itself is new. The reward for faculty participating in this exploration is the ability to enter a new field of research with funding provided and with the support of other faculty in the Center. Essentially, faculty are rewarded with the opportunity to do pioneering work.

However, funding per se is not sufficient for most CREST participants. In any CREST, some faculty members may have personal research support rivaling that of the entire Center. Their incentive is that they can both contribute and gain as a team player in the Center's pioneering work. Part of the validation of a Center's success, for the research manager, is the continued willingness of independently successful investigators to participate, even adapting their well-regarded work to the Center's vision.

A related challenge for the Director is in finding ways to build camaraderie and team spirit among researchers accustomed to working independently. The Director must be able to recognize the type of individuals who can be effective team members.

A significant challenge lies in the fact that industry has an inherently different vision than the Center faculty do. In general, they simply do not take as long a view. Consequently, industry's input can be a deterrent to the development of a vital, sustaining vision for the Center. Yet their viewpoints and needs must be taken into account in a way that maintains their commitment to the Center.

The corresponding reward, for the research management team, is in making industry a believer in the CREST's long-term plan and in helping industrial members understand that their needs will be met better by letting the CREST pursue its long-range plans. Several Directors have noted the satisfaction that comes with proving to industry, by means of actual results over a period of years, that this approach will benefit them more than having the CREST address their immediate needs would.

The cross-disciplinarity of the CREST's field of research can itself present challenges. An area can be so thoroughly cross-disciplinary that CREST faculty encounter difficulties in recruiting within the departments. Tenure and promotion are, of course, vital issues for young faculty members. Tenure and

promotion decisions are made in the departments—so the concerns are well founded. There is a risk that if the tenure/promotion process is handled through an academic committee within the department, researchers may tend to focus on publications at the sacrifice of securing funding or extending the research to a useful technology transfer. This prospect can be minimized if the Center Director and Associate Director for Research maintain close ties with the departments and ensure that they have a substantive, direct input to the promotion and tenure process within the departments.

Thus, one of the primary rewards of CREST research program management is seeing the CREST become accepted by researchers in associated fields and watching the mainstream move in the direction the CREST has already gone, so that faculty and students perceive participation in the CREST not as a career risk but as a career enhancement.

3-11. Chapter References

NSF Engineering Research Centers Best Practices Manual. Online at: http://www.erc-assoc.org/manual/bp_index.htm, accessed 8/04.

CREST Best Practices Manual
Chapter 4: Administrative Management

Contents

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EDITOR'S NOTE—this chapter is taken nearly verbatim from the Engineering Research Centers' Best Practices Web site (online at http://www.erc-assoc.org/manual/bp_index.htm), which may be consulted to compare and contrast with the CREST practices detailed below.

4-01. Introduction

This chapter addresses the daily operation of a Center for Research Excellence in Science and Technology (CREST). Suggestions are based on common experiences shared by existing Centers. However, there is no single "right" way to manage a CREST. Major differences among institutions call for diverse management strategies; know your university environment and utilize only those suggestions most useful to you. Over time the model of a typical CREST has evolved from a single-university Center, or an CREST located at one institution with collaborating affiliate universities, to multi-university partnership Centers consisting of a lead institution with a number of significant but subordinate partner universities. Regardless of the organizational structure of the CREST, the totality of administrative requirements is essentially the same.

Ideas, suggestions, and recommendations found in this chapter reflect the overall administrative needs of the CREST. Ultimate administrative and management responsibility and authority rest with the lead institution. However, the distribution of effort may be shared over several universities or among a number of individuals.

4-02. The CREST Environment

The first task facing the administrator of a CREST is an analysis of the environment in which the Center, and hence the Administrative Director (AD), will function. A thorough understanding of the "baseline" environment will enhance every aspect of Center management.

Make time to take stock of available resources and local circumstances. Failure to do so puts you in a reactive position. Effective strategies will differ based on size; public vs. private support; technical and industrial research areas; the current level of commitment from your home institution and opportunities to improve it; the requirements of collaborating organizations; the diversity of your student and faculty population; the age of your Center; etc. The following information is designed to assist the AD in analyzing factors that shape the Center's environment.

Structure and Organization—There is no ideal organizational scheme for a CREST; every Center will be (and should be) unique. Indeed, the creativity your CREST team brings to the development of the Center is apt to serve as a model for future developments within your home institution. There are, however, two things you can count on: change, and the need to be flexible. Be sure to consider the following questions as you organize your infrastructure:

Within your university, where is your Center in the organization chart? Will your Director report to an engineering department chair, dean, or some other university official? Will the Center be a financially autonomous unit with independent bookkeeping? Will you be directly responsible for the financial management of the CREST? If not, who will? Your internal planning will be heavily influenced by this internal structure. To the extent that your university financial management system allows, spend time and thought in developing the 'chart of accounts' for your Center. The 'chart of accounts' structure should become an essential tool for facilitating financial reporting.

If your Center is a part of a consortium: since one institution will be the lead on the award, how will the others interact and share in and contribute to CREST operations and resources? Failure to clarify and formalize these arrangements early on has led to serious problems at some Centers.

How is your university Office of Contracts and Grants (Sponsored Research) organized? Does it have separate "pre-award" and "post-award" units? Does it include sponsored program accounting and training for university accounting (e.g., OMB Circular A-21, A-110, Cost Accounting Standards, university policies and procedures)? You need to understand your institution's research management hierarchy and how it functions. NSF now requires an authorized university official to certify the Center's statements of industrial membership and support.

Do you have a copy of NSF's Cooperative Agreement? If not, obtain it, read it, and keep it on file, as it is the governing instrument for your award. Make yourself an expert on the nuances of your Cooperative Agreement; find out how it differs from normal grants and contracts. Keep a file of annual modifications made to the Cooperative Agreement. Expect to coach/train your grant administrator regarding the nature of an CREST. Often they will try to deal with your Center as if your award is a normal federal grant or contract and that would be very inappropriate.

Fiscal Year Differences—Most Centers find it necessary to deal with multiple fiscal and reporting years. Member companies will require unique fiscal periods, and the award years from NSF probably will not match your university fiscal period. These differences will have a profound impact on reporting requirements, staffing plans, and management of budgets, revenues, and expenses.

Life Cycle Changes Over Time—It helps to proactively anticipate major transition periods. Key events shaping the CREST often include meetings with industry; major external reviews (i.e., NSF annual reviews and renewal reviews in Years 3 and 5); building a new facility; any major remodeling activities and/or physical moves undertaken; and the eventual phase-down of NSF support in the later years of the award. Other significant events will happen, often without warning. Any such changes--the naming of a new CREST Director; changes in participating faculty or key program staff; change among top university VIPs; assignment of a new NSF-CREST Program Director; or significant shifts in funding and staff--will alter strategic plans for the CREST in unexpected ways.

Centers are vulnerable to any significant change affecting universities, government, or industry. Of special concern will be economic and business factors affecting your member industries. As the CREST develops management plans, try to remember that it is natural to have cycles of growth and decline within Center programs. Expect change; use the (inevitable) disruptions as an opportunity to improve!

4-03. Administrative Coordination of Center Activities

In most Centers, the Administrative Director will serve the entire CREST as the guardian of resources, policies, and myriad details. The operative word is service. To be effective, the AD must have some knowledge of all Center activities. Working closely with the Director, s/he must consistently maintain a "big picture" perspective. The Director and the AD must consider the needs of all stakeholders (NSF; member companies; the university; other funding agencies, including foundations, state or other government agencies; Center faculty; students; and other staff). With the involvement of the other leaders of the CREST, they must also balance potentially competitive internal resource demands (e.g., research, education, technology transfer, and management). The AD usually provides the "glue" that holds the various administrative functions of the Center together. The CREST Director will

count on delegating a great deal to the Administrative Director in order to protect time. This partnership is crucial and should be considered carefully when staffing this position.

The Administrative Director is apt to wear many hats. The AD usually:

- Assists the Center Director in the overall management of the CREST;
- Acts as guardian of rules, regulations, and policies;
- Serves as the information "gatekeeper" and resource for all members of the Center; and
- Is the Center's financial and personnel manager.

A word of caution: As your partnership with the Center Director evolves, be careful not to let him or her delegate to you responsibilities that should be carried out by the Director or the Executive Committee. Even though the confidence shown in you might be gratifying and the authority appealing, the consequences can be damaging, both for you and the Center.

Delegation is an essential skill for all CREST personnel. For the AD, the most frequently delegated tasks include those related to event management, communications, routine accounting and payroll documents, facility management, and Center tours. Functions that cannot be easily delegated by the AD include assisting the Center Director with strategic planning and policy development; financial management; staff development; and the design/maintenance of the CREST information system that supports Center reporting.

The AD plays an important role in the CREST's strategic planning by adding an operational perspective to the planning process. Among the considerations the AD should bring to planning are: personnel and staffing needs balanced with university, state, union, and other restrictions and requirements; an understanding of the life cycle changes of an CREST; budget constraints and requirements; and a Center-wide commitment to all CREST constituent needs and functions.

As a key member of the CREST management team, the AD is usually a member of important CREST committees. These will vary, to some extent, with each individual Center, but typical committees are:

- Executive/Management/Steering Committee (Center faculty and management)
- Education/Outreach Committee

- Facilities/Space Committee
- Budget Committee.

Management Styles—Centers attract creative, entrepreneurial individuals eager to build something new. Struggles over jurisdiction are to be expected. It helps to understand the natural tensions at work in the Center.

The need for strong, entrepreneurial leadership must be balanced against the need for internal structure, planning, and stable operating systems. (Enter the AD.) Everyone agrees that the ability to shape decisions and change directions rapidly is especially urgent during the earliest stages of the CREST life cycle; you must do everything possible to support your Director in meeting this challenge. Some suggest that these early "entrepreneurial years" should be followed by a managerial style focused more on planning and organization. Others among us believe that an CREST must always balance a dynamic tension between creative change and organizational stability. Indeed, this focus on innovation helps to explain the unique character of Engineering Research Centers. It also helps to explain the crucial need for a close, cooperative professional relationship between the AD and the Center Director, as well as other members of the Executive Committee.

Whatever the specific situation at your Center, you can expect a subtle shift in management expectations over time. As the CREST grows and matures, the exciting bursts of activity required to do something for the first time are replaced by a heightened focus on longer-term goals and mission achievement. Delegation, collaboration, and teamwork become increasingly important. To improve the CREST's ability to negotiate these transitions smoothly, it may be desirable for the Center Director and Deputy Director, the AD, and key faculty members to take courses in personnel management and team building.

4-04. Financial Management

In most CRESTs the AD is responsible for financial management. However, in some Centers this function is assigned to a financial specialist who may or may not report to the AD. As financial manager, the AD is the authorized representative of the CREST Director and usually has full signature authority. S/he is required to handle budgets, distribution of funds (under the direction of the Director and his/her Executive Committee), expenditure approvals, projections, and reports. It is the AD's responsibility to insure adherence to university and sponsors' policies and procedures.

Tip: Obtain copies of NSF Documents GC-1 (Grant General Conditions); CA-1 (Cooperative Agreement General Conditions) and GPM (Grant Policy Manual); be conversant with their terms and conditions. Request the documents from NSF by mail or from the following Web site: http://www.nsf.gov/cgi-bin/pubsys/browser/odbrowse.pl

The Financial System—A financial management system that complies with federal, state, and institutional regulations has been established at most universities. However, many institutions of higher education are currently overhauling their financial management and related computer systems. Your university may be engaged in extensive development projects. As a cross-disciplinary Center, your special needs place you in the thick of this activity. Again, determine your operating environment! You need to understand the financial reporting capabilities available on your campus. Specifically, how much help can you expect from the university's financial reporting system?

Questions to ask regarding your university system include:

- Does the university provide financial management information in a timely manner? Will reports reflect activity and encumbrances immediately, giving an accurate report of funds remaining?
- Do the codes embedded in your university's central system include all of the expense and revenue categories required for CREST reporting?
- Does the general ledger system allow you to post "soft" money or "pre-encumbrances"?
- Is the system interactive or query only? Can you set the parameters for the queries?
- Can you link your internal CREST system with the university system? CRESTs use both the centralized system and their own detailed internal system. How will you reconcile your internal records with the central ledger?

The University Chart of Accounts—The traditional hierarchical nature of the university is clearly evident within most charts of accounts structures. The assumption is that all organizational units within the institution are discrete, and fit neatly into this design. Because the CREST is interdisciplinary (and sometimes inter-institutional), a unique code may not be assigned to all relevant financial activity. This is inconvenient and inconsistent because:

- University reports are generated, organized, and routed based on this unit code (and, quite often, Center activity is embedded within various department records).
- Approval and access authorizations granted to the CREST within one university may not be consistent among all participating members of a partnership or consortium.

Because Centers have not been a part of the traditional structure, you have to persevere to gain access to university/college communication and representation networks. Your Center should, for example, be included on the "DDD" (deans, department heads, and directors) list. Center representatives should sit on relevant university committees, as well as attend key finance and personnel meetings. If routing of important communications is not automatic to the Center, you must take the initiative to remedy this situation.

The CREST Fiscal Year—Your CREST fiscal year will be based upon the funding cycle that is set by your NSF Cooperative Agreement. Other sources of funding may have different fiscal periods. Fiscal year-end differences will have an impact on the management of budgets, revenues, and expenses. Questions you will need to address include:

- Which funds can be "rolled forward"? (Must you "use it or lose it"?)
- How is "carry forward" calculated and managed? Is carry forward managed consistently for sponsored and non-sponsored funds? (At some institutions it is not, and this can cause special reporting problems).
- Will you need to budget split fiscal years for revenues and expenditures? (How will you reconcile different fiscal years in summary reports for all funds?)
- How will you "close" your books at the end of each fiscal year? What steps are needed to ensure that internal rebudgeting decisions are posted within the central system?
- How will you manage the grant's closeout and final reporting?

Financial Reporting Requirements—Financial integrity is critical to the successful management and continuation of the Center. Defining your Center's financial reporting requirements is a top priority and will shape internal policies and procedures. You will need to report to all of the organizations that provide support to the Center. You will also need to provide internal reports to Center management.

External to the Center—The National Science Foundation is the primary sponsoring agency for all CRESTs. As such, the NSF will require that you submit:

- The Annual Report and Proposal based upon your NSF award year;
- An "Indicators Report" on CREST achievements and activities (mostly quantitative), due on or about the same time as the Annual Report; and
- Special reports based upon specific one-time requests for information. You may also need to generate special reports on state, university, other federal agency, foundation, and industrial support received.

Internal to the Center—The CREST organization chart will help define your internal reporting requirements. The management team will determine what specific information is needed--by level (i.e., Center-wide, research area, research project); by category (e.g., personnel, travel, equipment); and by function (e.g., research, education, administration).

Specifically, you may need to report to:

- The Director (Center-wide summaries and function-specific analyses);
- Associate Directors for research, education, industrial liaison/technology transfer, and operations management;
- Research area leaders by research group and project leaders under research thrusts;
- Individual principal investigators participating in CREST research; and
- University administrators (e.g., dean, provost, president).

Developing the CREST's Financial Management System–New CRESTs will need to establish an internal "chart of accounts" system. It is very important to give careful thought to your coding system; this is the heart of the Center's internal reporting structure. For example, some Centers establish a "parent-child" account relationship in order to maintain stronger control of subsequent resource distribution. The "parent" account(s) may be sub-divided into various "child" accounts for the purpose of distributing funds to the proper research thrust and sub-thrust areas.

Budgeting—Budgeting takes place at all levels of the Center. You need to know who is responsible for budgeting at each level and within each management area. You will need to determine a consultation and approval process, and a timetable, for establishing "functional budgets" (e.g., research

funds by group; technology transfer; etc.). Be sure you know your Director's preferences.

Budget Preparation—Formal budgets are needed for:

- Each funding entity (NSF, State, university, sponsors); and
- Sub-contractors (this may include industry and/or other institutions).

The return of Facilities and Administration (F & A) funds is a significant factor in the budget of some Centers. If your Center has this good fortune, you will need to know how F & A recovery (ICR) return is determined, and how is it distributed. Get your ICR agreement in writing!

Management of Program Budgets—Identify who will be responsible for proposing and managing detailed internal budgets for each Center function. Detailed budgets will be required for: research, at the Center level and by thrust, project, and principal investigator; education, sometimes split by level/type (e.g., graduate, undergraduate, other); technology transfer or industrial collaboration; administration and/or management; infrastructure, including facilities, equipment, and computer networks; and other (e.g., for-fee-services provided; testbeds; etc.).

Leveraging Funds—The concept of "leveraged funding" is extremely important to the functioning of the Center and the achievement of CREST goals. By design, projects are highly interwoven and dependent upon one another.

The budget for a CREST may be complex, reflecting multiple funding sources with different award periods and different expectations. The AD needs to utilize funds to maximize the return on investment by each sponsor.

Your university contracts and grants system may not differentiate between a one-time contract to an individual investigator and the NSF Cooperative Agreement, with its assumption of multiple partners and leveraged funding. A mixture of long-term and short-term awards means that the Center budget may exceed the limited time frame set for most university budget development processes. Allocations will cross department, college, and institutional boundaries. Dealing with a system that is not geared to serve non-traditional units can be very frustrating. Yet CREST directors and administrators have been able to make sufficient adjustments, maintain a network of contacts, and negotiate solutions as the need arises. Under less-

than-ideal conditions, they have been able to establish successful, efficient, and service-oriented administrative organizations. With the increase in interdisciplinary activity in academe generally, it is hoped that universities will create and/or modify systems and procedures to facilitate the administration of Centers.

Rebudgeting—The CREST Cooperative Agreement (and "expanded authority") allows considerable flexibility for rebudgeting and cash flow management to encourage cost leveraging. Close communication with your NSF Program Director is essential. Remember that each CREST sponsor will be eager to leverage their investment in the Center and will be receptive to effective financial management strategies that make best use of total resources. Tip: You may find it useful to develop initial budgets for each major funding source, documenting the intended use or purpose of separate funds (e.g., corporate dollars to research and university dollars for management overhead), and any cost-sharing requirements. You will also need to manage cash flow aggressively to leverage your resources (e.g., through investments and/or savings of F & A costs).

Pre-Award Management—Each university has a proposal and budget review system that provides consistency in preparation of proposal budgets to satisfy both internal procedures and external regulations. This system is usually managed through the university's sponsored research office. It may be their responsibility to make sure that budgets are in compliance with regulations. This office checks for proper rates (e.g., employee fringe benefits and overhead), allowable costs, and that the budget is in compliance with the federal and state regulations.

Once the award has been received and reviewed by the university research office, a notice of award is sent to the CREST. The notice should contain the award/proposal number, budget period, any cost-sharing requirements, a continuation statement, terms and conditions, the principal investigator and key personnel, sponsor's code for type of funding, period of the award, report dates, and a copy of the cooperative agreement. You will need to obtain this information if it is not provided. The CREST financial manager (perhaps the AD) will develop operating budgets (based on the pre-award budget and the actual, final distribution from the agency) for the distribution of funds. You will need to coordinate with your central research and budget offices to establish new accounts and budgets.

In most cases, the pre-award staff will establish an account number for this award. This will enable CREST and university post-award managers to monitor all costs posted to the general ledger system. Account numbers are generally not created centrally until an award is received. When an award appears imminent and verification with the sponsor can be obtained, make a special request for a new account, to allow for the incurring of pre-award costs. Once accounts are established, continuation funds may be easily distributed. However, some circumstances require the establishment of new accounts each year upon renewal.

Post-Award Accounting—The university has policies and procedures for purchasing goods and services. Knowledge of these regulations and the funding agency's regulations is imperative. All staff must be aware of cost principles governing expenditures of federal funds (e.g., OMB Circular A-21) and procurement procedures prescribed by federal regulations (i.e., OMB Circular A-110 and Federal Acquisition Regulations, and the Cost Accounting Standards Board, or CASB). Both the post-award staff of your central university office and CREST personnel perform grant management functions. These staff have varying levels of authority to approve transactions and commitments. Be sure to confirm role expectations!

Specific post-award activities include:

- Account creation and maintenance
- On-line entry of budgets
- Receiving, recording, and depositing revenue (including special gifts)
- Keeping sponsorship and membership records
- Invoicing membership and service fees at the appropriate time
- Collection of past due amounts/accounts receivable expenditure review
- Financial reporting
- Communication with sponsors, auditors, faculty, and university administration
- Close-out of activities when grant funds end
- Documentation of cost sharing.

Payroll—Suggestions regarding the appointment of CREST personnel are provided later in this chapter. It is important to note, however, that two-thirds of the funding available to the Center is typically expended on people.

The financial manager must manage and/or clearly delegate responsibility for these activities:

- development of position descriptions
- keeping track of staff appointments, changes, and terminations
- payroll documents
- effort reporting
- compliance with union requirements
- negotiation/processing of classified vs. professional positions
- resolution of related issues (e.g., paperwork for visa/citizenship applications).

Accounting for In-Kind Support and Gifts—If the Center is the beneficiary of in-kind support (personnel, facilities, equipment, software, "deep discounts") you will need procedures to determine and record the value of those contributions or gifts. Become familiar with university policy and procedures for recognizing such gifts as revenue, and as items within the property accounting system. You will need to document the value of the gift. The value placed on people must include salaries and benefits. If the Center is the beneficiary of in-kind facilities and equipment, you will need to determine the value of facilities built at your site or made available for Center use (on or off site) and record the value and ownership of equipment either donated or made available for Center use (on or off site). Retention of all documentation proving the value is important.

Purchasing Systems—A system will be needed to support the acquisition of materials, supplies, and equipment in a timely and efficient manner. Determine who will process and track purchase documents, and who will be authorized to approve acquisitions. Purchasing may be centralized within the Center to provide monitoring control. However, this is more labor-intensive than distributed project management (purchasing done by participating departments). Any decision on appropriate purchasing strategies must involve the CREST Director, the AD and/or financial manager, and research

leaders. Decentralized support systems also require good networking between the CREST and departmental payroll and accounting personnel.

Plant Funds and Capital Equipment—If funds are available for physical plant/infrastructure needs, you need to know who will manage these funds. In some cases the expenditures for physical plant will also meet cost-sharing commitments and a full accounting will be required. Who is responsible for inventory records and property accounting? Depreciation is handled differently at each university; you need to know how your institution will deal with equipment purchased for the CREST.

Other Financial Activities—Managing the CREST also requires attention to several other activities that have a financial impact on the operations of the Center.

Record Keeping—The retention of certain information is imperative. Does your university have a central records retention area (sometimes now referred to as a "data warehouse")? If so, how much historical data is kept? Can you query for any fiscal period? How quickly can you develop a report using central records? The following information must be easily accessible to the CREST:

- Proposals and any revisions processed
- Notice of award, with terms and conditions
- Budget and expenditure detail
- Subcontracts with all associated documentation
- Copies of pertinent correspondence and internal/external approvals
- Copies of all equipment requisitions and any professional service agreements
- Copies of financial reports, including narrative/technical reports
- Copies of all service-related documents (e.g., internally generated invoices, etc.)
- Project/grant close-out documents
- Signed copies of all agreements (memberships, collaborations, et al)
- Copies of checks received as payments (memberships fees, et al)

- Copies of documentation proving value for in-kind donations
- Copies of all correspondence proving industrial relationships if a membership agreement is not in place

Be sure to check on retention policies; the CREST's grant period may exceed normal storage practices!

Audits—The Center is subject to both internal and external audits. Audits may be financial and/or operational. The general purpose of the university's audit is to show to the university that the CREST is well managed, in compliance with the university's own internal policies and federal regulations. An auditor may review all records, processes, purchases, and personnel records. It is usually the AD who manages the Center's response to any audit.

Closing Out Accounts and Grants—Final reports often are required internally by the university, in addition to the requirements of the sponsoring agency. Detailed information may be required including: expenditures; unexpended balance; personnel (including person-months per category); technology licensed; patents; publications; and a research progress report.

Staffing the Payroll and Accounting Functions—To maintain an excellent accounting system, it is important to appoint staff to handle high-volume, routine tasks (e.g., payroll documents, purchase orders, invoice processing, data base upkeep, etc.).

A crucial decision facing the AD and the Center Director concerns the level of training your accounting staff will need. Universities are rapidly adopting new, sophisticated financial management systems that require computer and accounting skills that may not yet be common at your institution. Essential qualifications are changing rapidly and most university job descriptions have not kept up. CREST accounting requirements will depend in part on how well your university's central financial system works; if it will be difficult to pull specialized reports from the mainframe, your staff will have to develop internal systems to meet this need.

4-05. Personnel Management

Effective staffing of the CREST is essential to the success of the Center. Yet the pressures of starting a new Center may lead to hurried hiring. Settle on an administrative structure before defining positions. Then proceed

thoughtfully in writing CREST job descriptions; taking time now prevents problems later! You might consider filling immediate needs with temporary personnel. Special planning is required to be sure that the needs of the Center are addressed.

Staff Size—All Centers report changes in staff over time, but no clear pattern of change has been documented. It is clear, however, that the Center's current position in the CREST life cycle (start-up, mature, etc.) will affect staff size. Extra effort is required the first time you do anything new; thus, demand for staff support may be especially high during start-up and during key times of transition. It is essential that the Director and AD discuss budget limits (and forecasts) frankly and realistically.

Determine how large your CREST is expected to become, based on your strategic plan, and consider how CREST staff can be used to extend faculty expertise and time (e.g., do you really want your faculty to edit newsletters, maintain databases, handle accounting transactions, maintain equipment, etc.?) Regardless of CREST size, it is the faculty who represent the core of the Center; all other staffing must be built around this base in order to leverage your most precious resource: faculty expertise.

Remember the need for flexibility in managing CREST resources! In drafting employment agreements, be poised to balance the pressures of CREST growth and new program development against a simultaneous need for downsizing and reorganizing due to program shifts and funding changes over time. Traditional human resource practices and layoff policies may not accommodate simultaneous retrenchment and reallocation within one administrative unit. Anticipating problems in this area can positively influence your early personnel choices, and may prevent grievances, conflict with unions, and/or future litigation. Plan early for the phase-down of NSF support.

Defining Job Descriptions—Some Centers have a very small staff. In addition to general administration of the Center, the Director and the AD may share responsibility for education programs, industrial collaboration, and outreach. This is not the most effective structure in the long run. Thus, the CREST Director typically appoints separate individuals with responsibility for administration, industrial liaison/technology transfer, education, and (sometimes) research management. A brief outline of essential CREST functions follows below.

General Management/Administration—Chapter 2 of the Best Practices Manual describes the responsibilities of the CREST Director. NSF now requires newly formed Centers to also appoint a Deputy Director; this position is filled by a faculty member within the CREST. A "generic" job description for the CREST Administrative Director (AD) has been attached to this section as Attachment 4-01.

It is important that the roles of Director, Deputy Director, and Administrative Director are clearly distinguished; responsibility for research and administration must be clear. It is essential that there be a good working relationship among these key individuals.

Research—All Centers appoint faculty managers for clusters of research projects or thrusts. Some also name an Associate Director for Research, although most Center Directors have retained this leadership role personally. These managers may hire additional technical and secretarial personnel. The majority of faculty and students are appointed through their participating academic departments.

Industrial Collaboration/Technology Transfer—There is significant diversity among CRESTs in staffing this function, and some Centers have struggled before finding the "right" approach to technology transfer. It is wise to evaluate optional strategies and to consider your environment carefully. For example, there are different advantages to hiring someone with an industrial, faculty, or business background. Ultimately, this individual must be familiar with the Center's research and be able to serve as a liaison between the faculty and industry representatives (including potential members).

Education—This management position is usually held by an CREST faculty member. The tasks of the Education Director or Coordinator vary across the Centers, but often there is a staff person who fills this role in coordination with the faculty. S/he is responsible for the development and execution of the Center's outreach programs, curriculum development, and course modifications. As with the technology transfer function, it is imperative that whoever has this responsibility work closely and well with the CREST faculty.

The CREST Main Office (reception, secretarial, administrative assistance)—Whether you have a one-person office or a large staff, remember that the individual who answers the phone and greets guests is the face and voice of the Center. This first point of contact is tremendously important and the position demands professional judgment and intelligence. The staff

responsible for "the front office" usually provide administrative assistance to the Center Director and other management personnel. At the same time, they must manage a sometimes daunting load of routine tasks. Many Centers have experienced problems trying to find and keep good people in these posts. Some Centers successfully supplement regular staff with student help. CREST orientation and training are critical for all staff.

Accounting—You must determine the level of trained accounting help required. Most Centers have found they need a dedicated staff position for daily accounting and payroll operations.

Information Systems—Staffing this function adequately may be pivotal to a smooth-running Center over the long haul. As a CREST matures, computer systems save valuable time and enable a small, coordinated CREST team to handle growing demands and constant change. Some Centers have added system administrators to their staff. Others rely on faculty, students, or existing staff to learn new technology. Be sure to determine how you will gain access to the expertise needed to design databases, develop downloading routines from central data warehouses, maintain a local area network, and build home pages on the World Wide Web.

Communication—There is a great deal of variability among existing Centers in staffing this area. This may reflect the fact that many professionals within the CREST are in a position to make creative contributions to Center publications. Certainly, all Centers must write, edit, and produce general and technical communications. A few Centers have dedicated positions devoted to graphics, editorial, and/or multimedia/computer systems support, while others have opted to outsource the actual production of publications. Also see the sections on Information Management and Communication for comments on electronic publishing. WWW capability is increasingly important, as NSF reporting and database systems now rely on the Web and outside contacts can use the Web to become familiar with your CREST. It can be used to provide special access for members to ongoing work and results.

In all support functions, budget and space will limit your staffing plans. Consider the use of temporary vs. permanent employees, student assistants, and outsourcing to university and external services or consultants. You will want to review the CREST's master planning calendar and evaluate peak periods and functional conflicts. For example, you might find that one person could coordinate annual report production, produce a newsletter, run the

industry meetings, and oversee the annual budget preparation process, if only these tasks didn't all peak at the same time.

When university students are employed, the Center must determine what constitutes appropriate student involvement that does not interfere with their educational objectives. Nonetheless, student employees have worked out very well for Centers. Duties vary from routine office tasks to dissemination of information on the WWW; technical assistance; coordination of REU and other educational outreach activities; and computer support.

Position Titles—Explore your university personnel system(s) before finalizing position descriptions. Don't limit yourself to the most commonly used classifications. Many Centers have found that existing university personnel titles and pay scales are outdated and do not fit their needs well. Chances are good that there are alternative titles and options open to you. Review overall Center functions/tasks, and then proceed to define specific CREST positions. Determine essential qualifications before you begin to recruit and screen individuals.

Your university already has central Personnel staff who can provide help. They can guide you in the use of employment categories/titles, and can help to ensure that the university complies with laws and regulations regarding recruiting, hiring, conditions of employment, and termination. The university's personnel policies also address regulatory issues such as equal employment opportunity, nondiscrimination, sexual harassment, and drug and alcohol abuse.

Before You Hire—You may want to consider alternative appointment strategies. For instance, under what circumstances should tenured faculty be funded by the CREST? Will the Center need to have the department hire new faculty? Some Centers do not pay participating faculty salaries; rather, continued department support of faculty lines is viewed as the appropriate "contribution" in return for student support and other benefits that come with Center involvement. Additionally, much of the funding that comes to the CREST is "soft" (not backed by continuing state allocations or private endowments.) Most institutions require "hard" financial backing for tenured positions. NSF will ask each Center to examine the progress of young faculty towards tenure.

Your Center may have the option to appoint non-faculty staff directly within the CREST, or else to process appointment documents through participating

academic departments. Which approach will better enhance cross-disciplinary cooperation within your institution? This issue also calls for an evaluation of several operational and resource concerns. You need to decide where students will pick up their checks, how much assistance you can expect from support staff in participating departments, and the availability of special university services (e.g., staff to work with individuals experiencing visa difficulties, etc.).

Be clear about conflict resolution procedures. The AD will receive requests and advice from all of the key players (internal and external to the CREST). Competing opinions and needs are inevitable. Personnel conflicts will arise when clear job definitions are not established. This may be especially difficult if there is not a clear understanding about who supervises staff and how problems will be resolved. Typically the AD will negotiate these situations, referring problems to the Center Director (and any committees or governing bodies), as appropriate.

You should recognize the important role the AD can play, through hiring decisions, in supporting the careers of women, minorities, and the disabled. NSF encourages diversity in the administrative staff of CRESTs as well as the faculty. On many campuses, CRESTs can serve as role models in how to do this well.

Special Challenges Facing Cross-Disciplinary Centers—Efficiency must be a special priority. Center processes must expedite collaboration across participating units. If, for example, it takes longer to hire someone, to get something purchased, or to process a grant, faculty will shy away from involvement with the CREST. Yet additional authorizations may be required and can easily lead to bureaucratic delays. Organization and planning are critical!

It is important to hire and consistently train all staff to enhance and facilitate activities in the participating academic departments. Relations with participating departments need to be nurtured carefully.

NSF site review teams will ask to meet privately with students and industry representatives during external site reviews. It will reflect poorly on the CREST if these individuals don't have a clear idea of what the Center does and what their role is with the CREST. The Center needs to find ways to build a clear identity with students and others without violating individual loyalties to existing organizations. It can be, of course, a powerful mechanism for

getting diverse groups together (students with industry, researchers from diverse disciplines, etc.).

Establishing your Center's identity as a unique entity on campus is important. Problems can arise, however, when both the home department and the Center vie for individual loyalties, resources, or recognition. The CREST must build a separate identity, without competing with participating departments.

How will your CREST involve participating department personnel directly in Center affairs? This may entail cooperative agreements for staff assistance; fund transfers between the CREST and participating units; shared accounting; etc. Coordinating with other department staff has several advantages: it gives home units control over some funds and activities; it documents and gives credit to participating faculty with their department heads; and it may save money by avoiding the need to expand accounting and support staff.

Evaluating and Rewarding CREST Personnel—Make time to thank staff and recognize them. While we all do it, we rarely do it often enough. There are many ways to recognize and support outstanding CREST personnel. Some examples:

- Develop a consistent performance evaluation process.
- Provide staff development and training (including time management; dealing with change; and computer skills).
- Experiment with team building/quality circles, etc.
- Attend professional meetings.
- Recognize staff at formal CREST meetings and events.
- Nominate outstanding employees for university awards.
- Develop flex-time policies.
- Support some social activities.
- Provide special rewards programs for internal system improvements.

Personnel Records and Reports—It is essential that an accurate and up-to-date record of all CREST personnel be maintained. Reporting agencies set guidelines on the type of personnel reports required (e.g., federal grants require effort reports on the number of hours devoted to the project). Check

the requirements for the tables in the NSF Annual Report and the NSF Indicators Report carefully.

Sponsors, including the federal government, require a wide variety of personnel statistics. It will be important for you to distinguish/track the following in your records:

- Headcount (the number of individuals) vs. FTE counts;
- Paid (salaried) vs. otherwise supported personnel;
- Directly supported students vs. those indirectly involved (as in taking CREST-influenced courses) to provide the total number of students "impacted" by the CREST;
- Historical information (e.g., personnel over time);
- CREST student detail;
- CREST faculty detail (e.g., core faculty vs. participating faculty; visiting faculty);
- Gender/racial/ethnic classifications and other personal data;
- CREST program affiliations and program changes over time;
- Time and effort reporting, for any personnel paid on federal funds; and
- Alumni information, including address after leaving the CREST.

4-06. Facilities Management

While contiguous space is the ideal mode to foster team building, especially among students, it is common for a CREST to begin life in discontinuous space across campus or "camped out" in temporary space. Faculty (and many students) will likely retain space in affiliated departments and conduct CREST research in those facilities. This situation continues for many existing Centers. To date, few CRESTs are housed in entirely new, contiguous space, although building is planned at several universities. The time to press for contiguous space is during the first year, when the pressure of the third-year renewal can be used to your advantage.

Defining Space Needs—When an Engineering Research Center is established, a planning group needs to define the Center's space and facility needs. Here again, knowing your university environment is very important. Each campus

offers unique challenges. The value of building a network of contacts across campus cannot be understated.

The following questions need to be addressed.

- What space is currently available?
- Is major renovation needed?
- Has the university pledged to share the costs of renovation or development of new space?
- Will you need to raise funds for the new space?
- Will you need to move into temporary space during renovation?
- When is that space available? What is the impact on research likely to be?
- Who controls facilities management within the university system?
- Will you need to deal with an outside architectural firm?
- Will you need to hire outside contractors?
- Who will be the "CREST Facilities Manager" during the construction period?
- Who will be the "CREST Facilities Manager" after the Center occupies the new space?

Identifying long-term facility needs is critical. Keep research, education, and technology transfer goals in mind. At what phase of the CREST's life cycle will specialized facilities be required to accomplish the long-range goals of the CREST? Negotiate agreements for growth as the CREST matures. Some universities have established requirements for retaining or gaining facility space based upon grant dollars awarded and F & A costs returned to the university. Another option for some Centers has been acquiring off-campus space. Check university policies regarding off-campus space prior to the planning stage.

Potential Space Needs—CREST functions to consider when identifying space needs include:

- Research;

- Conferences/meetings and seminars (needed for cross-disciplinary collaboration);
- Student carrels (undergraduate and graduate);
- Space for visitors (lab and office);
- Computer network/workstation facilities;
- Offices for administration, faculty, and staff;
- Training facilities;
- Multimedia laboratories and teleconferencing;
- Storage rooms and closet space;
- Security systems; and
- Signage.

Identify who will be responsible for allocating space within the CREST. Prioritize future needs (data/network connections; administrative vs. laboratory vs. storage needs; new laboratories; etc.). Always try to build in flexibility for (unknown) future requirements. Identify who will be responsible for keeping a schedule for all rotating space (e.g., the conference room).

Shared Space—Will the CREST be housed in existing space with other engineering units, or will it be assigned independent space on campus? There are benefits to either situation. Common-use space shared with other departments or Centers often comes with certain amenities (e.g., shared computer network facility costs; increased collaboration with other faculty members; and shared cost of laboratory renovation/remodeling and administrative support staff). If space is to be shared, be sure to secure written agreements, so as to avoid conflicts. Some CRESTs have shared labs for specific research groups. Some provide offices for students, while others have common areas for students.

Funding—The CREST must identify the source of funds for the purchase and maintenance of equipment, laboratory renovations, computers, and furnishings. Annual budgeting should always include a thorough re-evaluation of facility and equipment needs. Pursue all available options for matching funds (e.g., university, dean, equipment grants, individual PI grants, private foundations). See also chapters on Leadership (2) and Research (3).

Space use is a sensitive issue on most campuses; high-quality laboratory space may be especially limited. Encourage realistic consideration of long-term needs with maximum efficiency in mind.

Building and Remodeling—It is critical that one person from the Center be delegated to work with the appropriate architect, contractor(s), and building supervisor from the beginning to the end of the project. This individual will also work with CREST faculty and technical staff to oversee construction progress to: stage the move, keeping all parties informed of on-going experiments, research and teaching considerations, etc.; and plan for a transition with maximum efficiency and minimum disruptions.

It is helpful if this individual knows something about your technology and facility use. It is even more important, however, that s/he be a stickler for detail. You want someone overseeing the work on a daily basis who will be on-site, and who will nit-pick progress, estimates, and actual charges. Very significant savings can result from this careful attention to construction deadlines and costs.

Laboratory Facilities—If your Center laboratories (or testbed) operate as a service Center (i.e., charging user fees), your system must include detailed records of instrument use (including supplies used and technician time booked); billing or invoicing records; payments; and collection efforts. Facility planning must be an ongoing process throughout the life cycle of the CREST.

Some Centers have found it very beneficial to build an integrated information management system that allows automatic, electronic transfer of data from the initial scheduling of user time on instruments, to the billing clerk, then to the accounting department, and so forth. While it takes time to develop such internal systems, they may become one of the key strategies for survival as the CREST grows, and as funding levels off or declines. An adjusted user fee schedule may be needed for sponsoring companies versus other users.

Equipment—Tracking all equipment received by the CREST, whether it is purchased or a gift/in-kind, is very important. An inventory database needs to be maintained from the beginning. You will need detailed records of equipment purchases, maintenance contracts, equipment fabrication projects, and any documents proving value for the gift/in-kind. You may need to coordinate equipment fabrication projects with your property accounting and sponsored research offices. Often a special code is required

on your documents and in your records, so that overhead charges and depreciation are handled correctly by the institution. You will probably want your system to be capable of tracking capital equipment authorizations, as well as actual expense as it hits your general ledger. You will also need a record of the portion of total cost born by different funding sources. Often, central university systems fail to give you this information. Knowing the location of equipment can be crucial during an audit.

Identify maintenance needs for equipment purchased. Service contracts can be very expensive but may, in the long run, save significantly on down-time, support personnel, and replacement costs.

Office Space and Services—The Center must provide necessary services to faculty, students, and others on site. These may include access to keys, telephone and fax services, office supplies, computers, printers, copier, and mail/package delivery.

Staffing Facilities Management Functions—Assigning office space is usually the AD's job. In some cases, the Administrative Director is also directly responsible for overall facilities management. However, other Centers have found it necessary to hire a lab manager, who works with the AD, faculty, and technical staff to oversee laboratories and equipment and to handle maintenance, cleanliness, and safety (ensuring that the CREST meets federal/state standards and training requirements). This decision depends on the size of the CREST, the level of university support provided, and the availability of funds to support equipment and facility development.

If the CREST does manage a large facility, it is important to assign a building supervisor. This person is responsible for making sure everything is working properly and knowing whom to call to get problems corrected. For example, attention to lights, air conditioning, fume evacuation systems, heating, elevators, fire alarms, et al., will be required. In some Centers, this individual may also coordinate group tours.

4-07. Information Management

As early as possible, the CREST should have in place a systematic process for collecting and storing the large quantities of information needed to manage a multi million-dollar operation. It is very important to examine your information needs before you build computerized data files (or employ a programmer). Find out what information is required for major reports

required by your sponsors. Consult key customers of the Center's information system. The objective is to collect all the information you will need and as little as possible of the information you will not need.

In considering database design and implementation, you must also take into account the shape of the university information systems and any others from which you will be extracting data. CRESTs with many institutional partners will have to determine the most effective and cost-efficient way to gather and input data across the institutions and miles. Developing a web-based system offers the benefit of cross-platform access to the information system and allows for remote site entry. It is best to begin as soon as possible to share information files electronically within the CREST. For reporting purposes, it is ideal if the information is integrated into an information management system. Since some of this information will be deemed confidential, or sensitive in terms of CREST self-interest, you need to carefully consider a set of issues related to computer security and local area networks.

Essential File Elements within the Center's Information Management System—Key information needed by the CREST includes:

- Mailing list (a single, coordinated list for the entire Center)
- Calendar (at least keep one for the core CREST office team)
- Personnel (include faculty, staff, consultants, and temps!)
- Students and alumni (include a history of CREST fellowships, stipends, employment, and gender/minority/disabled status)
- Industrial memberships (include a key interactions log)
- Invention disclosures, patents and licenses
- Publications (all should formally acknowledge CREST Program support)
- Capital equipment and assets (purchased and donated)
- Financial records
- Grant proposals (include pre-award authorizations and end dates to monitor for NSF base award and any supplemental awards from other agencies)
- Inventories (e.g., CREST computer hardware and software, licensing agreements)

- Detailed information on outcomes and impacts of the CREST on technology advancement

You will also need a record of CREST activities. For example, you will want to record attendance, by category, at major meetings and workshops; industrial visits to your Center; research on-site by industrial participants; and research activities or visits at member companies by CREST faculty and students.

Hardware and Software To Get Started—Existing Centers use a wide variety of computer equipment. Most are utilizing local area networks comprised of PCs and/or Macintosh computers. The NSF CREST program management is mostly PC-based, but some Program Directors use Macs. Conversion software and electronic mail have reduced the difficulties once experienced due to the diversity of hardware and software in use. Microsoft Word currently seems to be the most frequently used word processing program. There are many different programs in use for desktop publishing and graphics; you will want to explore the capabilities of software to handle scientific formulas and special symbols in use at your Center. The majority of current CRESTs use Filemaker Pro or Access for their databases. However, Excel, FoxPro, and other custom programs are also used.

Information management systems evolve over time. While technology is constantly changing, the management information system should be consistently managed to relieve pressure on staff. This becomes essential as resources stabilize (or fall). Initially, you will be consumed with the creation of the system. However, don't neglect issues related to maintenance and security. You will need to test your system against central capabilities, as well as audit requirements and other regulations. Historical retention of data is crucial and usually must be maintained within the Center. You will need to determine what records are public. You will need to establish rules about who can enter/edit your data and who can read it.

About Financial Records—For any enterprise as large as an CREST, keeping accurate financial records is crucial. The majority of existing CRESTs use spreadsheets (usually Excel) as their primary financial management tool. A few of the Centers also keep essential fiscal data in an internal database or data warehouse. Key files include the CREST chart of accounts; a historical record of CREST income; and annual records of budget, revenue, and expense. You must also keep track of indirect support to the CREST: projects

supported directly to the PI, not through the Center, but consistent with the research vision of the Center.

If your Center manages invoicing, you will need a detailed record of invoices and payments, including all efforts made to collect overdue accounts. If your Center allocates CREST funds to participating departments or other universities through an outreach program or under a joint institutional arrangement, you will need to anticipate these needs, hold funds to meet them, and keep a detailed record of fund transfers. Some Centers need to keep a history of subcontracts. You will need detailed records of capital equipment purchases, maintenance contracts, and any equipment fabrication projects. In order to comply with NSF's requirement that your Sponsored Research office verify your membership lists and funding sources, you will have to have records of membership agreements by firms, invoices, accurate data on in-kind contributions, etc.

Other Data Gathering Challenges—Many Centers report that the most difficult reporting area is technology transfer. This difficulty may reflect the number of people and interactions involved, as well as the sensitivity and technical nature of these exchanges. You will want to plan this aspect of data gathering with your faculty and with the CREST personnel responsible for industry collaborations. The Center needs a strategy for capturing information on company visits, student and faculty time at companies, technology transferred, success stories, technical and economic challenges affecting your industries, and more.

You need to determine what kinds of and how much information you want to keep. Some potential metrics are:

- the participants on Center research projects;
- the number and category of individuals paid by the CREST;
- summer students;
- enrollment in an CREST class;
- the number and type of participants in Center workshops or meetings;
- CREST seminar attendees;
- special visitors to the Center (e.g., high school students);
- CREST personnel who conducted research at a member company;

- the individuals who presented a talk and/or poster at your CREST meetings;
- industrial representatives who work with your core faculty;
- CREST individuals who are award recipients;
- CREST alumni who went to work for a member company;
- member companies;
- how member companies participate and support the CREST;
- the duration of their membership; and
- CREST and CREST individuals' publications.

It can also be difficult to capture information on diversity (i.e., ethnic, minority, and visa status). You will probably want a standard form that all students use to voluntarily self-disclose this information. Be sure to refer to current federal classifications for codes for these categories of people.

Keep track of your graduates from Day One! You will need to know what happens to them, where they go, and how to reach them - for the CREST's purposes as well as NSF's. (NSF periodically surveys CREST graduates and their supervisors.) It is best to design the information collection process to capture information on graduates systematically, at the end of each university term. Get to know the department staff responsible for processing graduating students. They are an invaluable source of information. Have a plan for how you will communicate with alumni, and do so at least two or three times each year. (The latter is important because of the postal service's mail-forwarding practices.)

No matter how difficult, all data collection is made significantly easier by adequate pre-planning and appropriate design of the information system.

Collecting Information from Your Faculty—Most CREST ADs agree that collecting information from a busy, dispersed faculty is one of the most significant challenges during the early years in a new Center. Remember that your scarcest resource is faculty time. Making information collection and reporting as easy as possible becomes one of the primary ways for you to demonstrate the excellence of the service that CREST support staff provide to Center faculty.

Other information resources not to overlook include:

- Department CV files for all tenure-track faculty;
- Your own research reports and newsletters (make sure the CREST has a schedule for these communication vehicles; gather information on publications, graduates, and new personnel regularly, as part of the information collection process); and
- Travel authorization documents (these documents give essential information on faculty interaction with companies and other universities).

You will need a systematic process for capturing and entering all of this information into your CREST database(s) in a timely, routine manner.

The NSF Annual Report—Develop a timetable and a standard operating protocol for this annual effort; define responsibilities well in advance of deadlines! Set up templates (and style guidelines); distribute and collect text electronically. Obtain a scanner; avoid re-keying information. Be sure the Center office has appropriate software to coordinate different text, tables, graphs, and charts. Consider keeping an "Annual Report in-box" (in hard copy as well as on your Web site) all year long; encourage CREST personnel to contribute useful information (e.g., copies of newspaper articles, announcements, et al.); this should also be useful in your general communications such as newsletters.

As the Center prepares the different sections of the report, create a text "tag" for incomplete sections, with instructions and a brief statement on what information is still needed and who is responsible for that information. The tag should be noticeably different in font size/color in order to be distinguished from the rest of the document for easy removal. Ideally, the timetable for preparing the Annual Report should be set to allow time for the first completed draft to "grow cold" before final editing. Good luck!

The NSF Indicators Report—One person needs to coordinate this effort; this will probably be your job as the Administrative Director and liaison to NSF. Design your information system with the Indicators in mind. Document your work; keep a record from one year to the next of how you counted things. Gather information continuously, systematically. Ask your Industrial Specialist and Education Coordinator to be responsible for appropriate tables; however, it is your responsibility to make sure the Center has the backup documentation. Decide how you will determine "best examples" of research and education accomplishments (sometimes known as "nuggets," or most

important developments). A scrapbook of media releases and/or newsletters on the CREST's accomplishments may be a good source of such "nuggets."

Information Gathering via E-mail—Make good use of e-mail and save this correspondence. Generate a common CREST e-mail directory and a set of group aliases; share them across the Center via your administrative server. Assign someone to maintain this file, and alert your people when changes have been made. Examples of helpful group aliases include: all CREST personnel; all faculty associated with the CREST; graduate students; undergraduate students; administrative support staff; and program or thrust leaders.

Individual personnel are able to set up private archive files for e-mail. It may also be useful to set up standard e-mail files (or "mailboxes"). For example, your Center might utilize a mailbox for the Annual Report, one for conferences, newsletter information, Indicators, and other job-related information.

Finding the Computer Expertise the Center Needs—Currently, existing CRESTs are managing to find this help in a wide variety of ways. For some Centers, computing is part of their mission, and they can draw upon faculty and student expertise within the CREST. Others must hire, train, or borrow such expertise. While most CRESTs have LANs (local area networks, with one to twelve internal servers), there does not seem to be a consistent pattern to staffing solutions. This is an area that is changing very rapidly, and there is no single right way to proceed. You will want to keep an ear to the ground for developments within your institution and in participating departments. Obviously, someone should be assigned to monitor changes in available technology and to make recommendations periodically to the Center on purchases and upgrades. Sometimes you can share specialized resources and expertise with the departments.

Managing Your Information System—You will need a Center policy on the use of unauthorized software, virus checking, and frequency of required password changes. It is likely that individuals within the Center will want to share information electronically via internal servers (i.e., a LAN). This immediately raises management and security issues to be addressed. It is wise to draft a specific set of expectations for the person identified as the LAN manager. You may also wish to explore the use of "firewalls" to preserve the integrity of your information from external network users. The central

computing office at your home institution should be able to help with these issues.

4-08. Communication

Communication Within the CREST Community (and Beyond)—Teamwork is essential. You will want to be sure that staff working on technical reports and newsletters are coordinating closely with administrative and data management personnel. These may not be the same individuals.

All Centers prepare technical research reports. Some CRESTs fill reprint requests, and some do not. (The cost of sending reprints and other materials overseas is an issue at most Centers; the Center's Web page may increasingly provide a solution here.) All Centers should have a newsletter, as the need for one appears to grow with time; common practice is to publish two or three issues per year. A CREST brochure is a common need. (NSF periodically prepares a two-page, glossy "fact sheet" for each CREST, along with an overview description of the CREST Program. These flyers can be useful for marketing.) Most CRESTs maintain a set of standard information materials that can be assembled into an information packet; standard items include fact sheets, faculty bios, information on equipment/lab use, and copies of recent publications. Some CRESTs prepare a "public" version of their NSF Annual Report, although this is not a standard practice.

All publications indicated above can be made available to the CREST's partners through the Center's web site. If publications, meetings, and reports are considered benefits to industrial partners, a secured section of the web site can be developed. While this allows instant publication of any Center media as well as opportunities for on-line registration to CREST meetings, a secured site requires constant maintenance of security. Companies are not always responsive to requests to update user lists, so the AD and the industrial liaison need to work together to keep track of appropriate users from member companies.

When asked to prioritize target audiences (for whom communication vehicles and strategies are devised), CREST administrators ranked them as follows:

1. Companies, including prospective members;
2. Prospective students, and CREST alumni;
3. NSF and state personnel working on economic development;

4. University VIPs and participating departments;

5. Other parts of the home university and other universities, including other CRESTs, state legislators, and local press; and

6. National legislators, national press, the general U.S. public, and international interests.

Consider forming a communications team to oversee your publications and contribute editorial feedback. A few givens need to be considered, no matter how you approach the communications function:

1. Someone at the CREST is going to have to understand and oversee activities that depend on computer-generated graphics and desktop publishing. This now includes Web page development and conversion of documents into HTML format.

2. Producing something like a newsletter or an annual report is a time-intensive activity. You will need to plan staffing expectations realistically. You will also want to examine the timing of all CREST reports and communication devices (paper and/or electronic) and strategically stagger their distribution with major events that take place each year.

3. Your publications reflect the image of quality your Center hopes to project. Quality standards need to be determined.

4. In the early years, communication will be terribly important for recruiting companies, students, and sponsors. At some point, however, you will need to evaluate the cost-effectiveness of your communication efforts. Given the limited resources and keen competition that characterize grant years 5 to 10, you may need to reconsider your target audiences and carefully select any mechanisms for reaching out to the general public.

The World Wide Web—It is questionable to try to suggest any "best practices" for Internet use, as this area is changing so rapidly. While debate continues over whether or not Internet communications will entirely replace traditional forms of information collection and distribution, it is likely to play a larger and larger role. Already the Internet offers a major alternative medium for certain types and purposes of communication. Therefore, it is important to look at each type of information, determine the intended audience, and then publish and manage the materials appropriately. Every CREST ought to develop a Web site to reach a variety of audiences.

We must be careful not to get distracted by the changing "presentation technology" of the Web. While this technology will allow us to distribute more diverse forms (images, video, sound, etc.) and improve communication options, fundamental audience analysis shouldn't change. The cost-effectiveness of various strategies must be addressed. Who are you trying to reach, and what are the best ways to reach them?

4-09. Event Management

Meetings play a crucial and vital part in the life of a CREST. During the course of the year, a typical Center will host at least three major events: two industrial meetings and one NSF site visit. Additionally, most Centers must also manage a wide variety of smaller events, including faculty and staff meetings; small group meetings between faculty and industry researchers; orientation programs for new students; seminars; workshops; short courses; and social events.

It is important to realize that universities differ in structure and in their approach to event management. Hence, what works for one Center will not work for another. However, this section provides a few guidelines to provoke your thoughts about preparations for a major CREST meeting.

Industrial meetings serve a variety of purposes. Of chief importance is the opportunity for a two-way interaction with your industrial sponsors. This includes obtaining input from industry on the direction of research and education. NSF site visits allow a team of external industry, university, and NSF reviewers to assess the progress of the Center and to provide suggestions or corrective actions to assist in the growth of the CREST. Continued funding depends, in large part, on the results of these external reviews.

Preparation for these meetings is critical. Effective internal coordination can influence the substantive outcome of a meeting.

Before the Meeting—Highly successful events depend on advance planning. Early decision-making must involve the Center Director and other key CREST personnel. Some of the most time-sensitive considerations include these:

- If you want the "right" people there, set the date early! Be sure there are no major conflicts with the CREST schedule, university calendar, major professional meetings, or holidays (don't overlook major Jewish holidays). Some industrial

participants must schedule their travel plans a year or more in advance. Some conference Centers book peak times two or more years ahead. Consult your NSF Program Director to set site visit dates.

- Most Centers have found it useful to coordinate ancillary events with their main industrial meetings; this increases attendance and saves money and time. Decide how many separate events are desired, including short courses, workshops, lectures, committee meetings, tour of facilities/labs, and poster sessions.
- Encourage faculty and industry leaders to collaboratively plan the purpose/agenda for events. Be sure you know who is responsible for technical coordination (e.g., the faculty member responsible for a particular workshop).
- Determine who should be invited and estimate numbers. If the Center sometimes pays expenses for external speakers, clarify expectations in advance. Note that NSF and industry have placed growing emphasis on presentations by students and young faculty.
- Confirm the budget, including funding expectations for meals and travel. Ascertain the availability and necessity of discretionary funds for alcohol, meals, payment of honoraria, etc. Is a registration fee required? If so, keep it low! Industry resents paying twice.
- Reserve meeting space, and secure advance contracts with hotels, caterers, and transportation. Outside vendors may require significant lead time, and usually have preferred and/or negotiated rates with the university. While it may be cheaper to go off campus, NSF and industry prefer that site visits be held on campus to permit access to labs and students.
- Establish a planning timetable; determine the date invitations should go in the mail, and secure internal commitments to meet this goal. The assignment of tasks and a timetable (with clear internal deadlines) should be distributed to key faculty and staff, in writing.
- Logistics to be considered include: meals; handout materials; supplies needed (including special paper stocks, signs, etc.); audiovisual equipment; transportation requirements/contracts needed; a firm deadline for confirming speakers and final agendas; and a meeting date for last-minute briefings to staff.

During the Meeting—Most Centers have found written checklists to be invaluable. No matter how well you plan a meeting, something unfortunate and unexpected is bound to happen! You will laugh about these "horror stories" later, but their inevitability reinforces the need for good planning

before and after the event. Plan backup systems and reconfirm all arrangements a day or two before the event.

After the Meeting—Allow time for the natural "letdown" after a major event, but do plan for a post-meeting wrap-up session with your staff. Capture, in writing, the ideas that people have for next time. One strategy that has worked well is to give all of the staff three cards: Ask them to write down at least one thing that went wrong (e.g., needs to be prevented next time); something that worked especially well (i.e., should be repeated); and a question or suggestion. (As chief organizer, you may be too close to the details, and might have overlooked something that causes confusion for others.)

Do not let down your meeting momentum until all of the following have been accomplished:

- Pay speakers and reimburse faculty and staff.
- Edit and mail minutes (or other follow-up materials).
- Update databases (industry, students, etc.) with appropriate information.
- Prepare final expense report, and update budget for future events.
- File all copies of meeting information and handouts in the master files. (Trust us: you will need them!)

4-09. In Summary

CREST administrators find themselves honing a unique set of skills as the Center develops. You will stretch the boundaries and limits of your institutional systems, and you will challenge policies originally designed for simpler times. As the CREST matures, you will come to depend more and more on the team of people around you and on the network of professional contacts you have developed. The CREST staff you lead will need to be as outstanding as the faculty, students, and companies you serve. The pace will be fast, and change will be a constant. There will not be any simple formulas for how to organize things, because each CREST is different. Thus, we end this advice as we began it: Know your environment. If you have questions, don't hesitate to call your peers at other CRESTs.

4-10. Chapter References

NSF Engineering Research Centers Best Practices Manual. Online at: http://www.erc-assoc.org/manual/bp_index.htm, accessed 8/04.

Attachment 4-1:
Generic Job Description: Administrative Director

NSF Centers for Research Excellence in Science and Technology (CRESTs) are dynamic organizations serving industry, university, and government needs in rapidly changing high technology areas. A complex organization, the CREST has multiple missions (research, education, and service) and is accountable to multiple funding sources (federal, state, university, and private). The Administrative Director reports directly to the Center Director and will manage multiple fiscal years; many different sets of rules and regulations; an annual budget of $1 million; an average of 24 full-and part-time researchers, faculty and students; supervises a staff of more than 50. Administrative duties include any or all of the following areas of expertise:

- **Financial Manager:** Responsible for budgeting, accounting, and reporting in order to maximize efficient use of funding, while ensuring compliance with rules and regulations.

- **Personnel Manager:** Hiring, supervision, and development of Center administrative personnel; manage documents/human resource policies for academic, research, and student appointments.

- **Information Systems Manager:** Oversight of management information system and report generation process (multiple reports to sponsoring agencies, university) and response to requests with accurate and timely information in format required.

- **Liaison with University/Sponsoring Agencies:** The CREST's guardian of university and agency system requirements (federal regulations, proposal processing, etc.). and responsibility for networking with university administration and NSF to keep abreast of latest changes.

- **Other Duties As Assigned:** Event management, communications, and public relations, as assigned. Some CREST administrative directors also have responsibility for outreach and/or education functions--for example, the summer Research Experiences for Undergraduates (REU) program.

Attachment 4-2:
Administrators' Glossary

Accrual accounting: The process of recording an expense when it occurs, rather than when it is paid.

AD: Administrative Director

A21: Circular A21 (from the Executive Office of the President, Office of Management and Budget) defines which costs are allowable as charges to contracts and grants.

CASB: Cost Accounting Standards Board, details federal guidelines for allowable costs to federal grants and contracts.

Cooperative Agreement (CA, NSF): Type of award that may be used when the project being supported requires substantial agency involvement during the project performance period.

Co-PI: Co-Principal Investigator

Cost Sharing: Financial contribution by the grantee. More common to research grants; a form of matching.

CRADA: Cooperative Research and Development Agreement; may be used by federal laboratories.

EEO/AA: Equal Employment Opportunity/Affirmative Action

E-mail Aliases: A file on your computer (or server) that contains the e-mail addresses of groups of people with common interests or organization to whom you regularly send electronic mail.

CREST: Center for Research Excellence in Science and Technology.

FEDIX: An on-line federal database with e-mail service targeting research and education funding opportunities.

> FEDIX
> 555 Quince Orchard Rd.
> Suite 360, Gaithersburg, MD 20818
> phone: (301) 975-0103
> http://web.fie.com

Fellowship: An award made directly to an individual in support of specific educational pursuits; *not* an employee. (Traineeships differ; check award conditions on training grants for service and/or pay-back requirements.)

Fixed-Price Contract: A contract providing for a set lump sum payment upon satisfactory performance of the terms of the contract.

FTE: Full-time equivalent (e.g., two half-time employees represent one FTE).

Fund Accounting: The accounting system used by the federal government and some universities to identify revenues and expenses according to the source of funds. Separate records are kept for assets donated to an organization and restricted by donors to certain specific purposes or use.

GPG: NSF Grant Proposal Guide

Grant: Type of award under which NSF agrees to provide a specific level of support for an initial specified period of time, with a statement of intent to provide additional support of the project for additional periods provided funds are available and the results achieved warrant further support.

Indicators Report: Report required by NSF from all CRESTs, due on or about the same time as the Annual Report, for reporting tangible measures of financial activity, personnel utilization, industrial collaboration, technology transfer, and outreach. Utilized by NSF to compare Centers in reporting to congressional and other bodies.

In-Kind contribution: A service or item donated in lieu of dollars.

Internet: An integrated system that links computers (and organizations and persons) around the globe. Through this system, information can be sent and received electronically. A loosely organized international collaboration of autonomous, interconnected networks, supporting host-to-host communication through voluntary adherence to open protocols and procedures defined by Internet Standards, typically based on the TCP/IP protocol suite.

LAN: Local Area Network--A collection of equipment, connected via a computer or special "server," to meet the specialized needs of the organization that creates it. Allows electronic transmissions between computers and peripherals such as printers. May be connected to other, external networks (e.g., the Internet).

Matching Funds: Financial contribution by the university required by a granting agency as a condition for receiving a contract, grant, or award.

MIPR: Military Interdepartmental Purchase Request. Used to transfer funds between agencies (e.g., to the CREST via NSF).

NACUBO: a professional organization.

National Association of College and University Business Officers
One Dupont Circle, N.W., Suite 500
Washington D.C. 20036
(202) 861-2500
http://www.nacubo.org

NCURA: a professional organization.

National Council of University Research Administrators
One Dupont Circle, N.W., Suite 220
Washington, D.C. 20036
phone: (202) 466-3894
http://www.ncura.edu

PI: Principal investigator on a sponsored grant.

RFP: Request for Proposals

RFQ: Request for Quotations

STIS: Science and Technology Information Service, an on-line search system of the National Science Foundation.

Sub-contract: An agreement or secondary contract in which a third party agrees to perform some of the activities defined in a primary proposal; agreed upon at the time of submission but not consummated until after the award has been made to the organization submitting the primary proposal.

TAC: Technical Advisory Committee, an industry advisory group required by NSF for each research program or "thrust."

Technology Transfer: The transfer of intellectual property between the CREST and the private sector.

Testbed: Experimental proof of concept, technology demonstration, pre-prototype.

World Wide Web (WWW or Web): A network and software system that provides hypertext access to the Internet. (Note: there are other ways to access the Internet, e.g., Gopher.) A Web address or domain describes the specific Internet location (e.g., http://www.cnn.com) where a Web site can be found.

CREST Best Practices Manual
Chapter 5: Education Programs

Contents

Date of last revision: 10/04

EDITOR'S NOTE—*this chapter is taken nearly verbatim from the Engineering Research Centers' Best Practices Web site (online at http://www.erc-assoc.org/manual/bp_index.htm), which may be consulted to compare and contrast with the CREST practices detailed below.*

5-01. Introduction

In the CREST program, quality education in science, technology, engineering and mathematics (STEM) is equally as important as research excellence and technology transfer. The goal of CREST education programs is to develop a team-based, research-inspired, and industrial practice-oriented culture for the education of graduate and undergraduate students that will produce STEM leaders for the future. CREST graduates make up a new generation of STEM practitioners who are adept at the cross-disciplinary team approach to problem solving; who understand and share industrial perspectives on research, design and manufacturing; and who are well-prepared to contribute productively to industry as a result of their experience with CREST projects. An important feature of all successful CRESTs is active outreach to involve faculty and students from other institutions in CREST research and education programs. This includes outreach to precollege students and teachers aimed at introducing STEM concepts in precollege education, in order to stimulate interest in STEM careers. It is also vital to increase the involvement in STEM of underrepresented minorities, women, and persons with disabilities. CRESTs are charged with enriching engineering education at all levels by integrating their research findings into new curricula for students and practitioners.

This chapter reviews CREST's education activities. It is aimed at a diverse audience, Centering on those operating or planning to operate CREST education programs, but also extending to faculty and staff of all university-industry research Centers and STEM educators generally. It addresses issues of program planning and direction, including management roles, strategic planning for the education program (including "life after NSF"), funding, and the role of NSF in developing and enhancing education programs. It describes the broad spectrum of CREST education programs for graduate, undergraduate, precollege, and community college students, including ways to increase the involvement of underrepresented populations. It discusses curriculum development in all its aspects. It reviews outreach techniques for making contact with sectors outside the university. Since interaction with industry is particularly important for CRESTs, it points out ways to increase

industrial involvement and interaction. Educational outreach to other institutions is explored, reviewing both domestic and international activities and their benefits to the Centers. The chapter describes educational delivery systems, including the Internet, with a review of effective applications of hardware and software systems designed to affect the curriculum. Finally, it summarizes some of the lessons learned in developing CREST education programs.

5-02. The Role of Education in CRESTs

Concerns about U.S. industrial competitiveness and science literacy have been widespread since at least the mid-1980s. Particular criticism has been levied at the hands-on experience that STEM students receive that may better prepare them for careers as STEM practitioners. Traditional STEM students obtain little practical experience in their education. Many large corporations find that they must provide significant training beyond on-the-job experience. Furthermore, although industrial employers place high value on teamwork, most graduating STEM students traditionally have had limited experience in working in teams.

CRESTs are designed to produce graduates who excel in these areas, where traditional graduates fall short. The Centers try to bring to engineering education a new culture based on goal-oriented values, complementing the theoretical science-based education long predominant in academic engineering. CREST education programs are a primary means of achieving the overall goal of culture change in engineering education, and in academic engineering generally. They encourage that change by articulating the CREST ideals, making opportunities available to implement the ideals, and facilitating the use of those opportunities. Faculty buy-in is essential; only if the faculty believe in the CREST educational/cultural model and act accordingly will CRESTs succeed in their mission to change the overall culture of academic engineering.

Education may actually be the Centers' most important means of contributing to the nation's global competitiveness. CRESTs devote much energy and resources to "spreading the culture" through education, and to creating an environment conducive to this new kind of education.

5-03. Unique Features of CREST Education Programs

Certain characteristics are common to nearly all CREST education programs, reflecting NSF's education goals for the CRESTs: a strongly cross-disciplinary approach, an emphasis on the involvement of industry, innovative use of educational technology, and a dedication to reaching far beyond the host universities to include a diverse group of students of all ages who might be inspired to become engineers or scientists.

CRESTs encourage students to work in teams by focusing them on engineered systems that require input from various disciplines, such as manufacturing, materials processing, biomedical systems, multimedia technologies, or earthquake engineering, with an awareness of technology and product development issues. Direct interaction with industrial researchers, both on campus and at industrial sites, is a vital feature of CREST education. CRESTs emphasize engineering design and synthesis, with a strong coupling between research and education programs. In addition, they devise innovative undergraduate and graduate degree programs and courses and update curricula and course materials as new research discoveries occur. Because of this approach to education, employers in industry often note that CREST graduates are more effective and productive than their traditionally trained counterparts. For more than a decade, these graduates also have provided a new dimension to education as they have joined the faculties of engineering schools across the country.

Collaborating with other CRESTs and other universities and extending the CREST experience to precollege students and teachers as well as businesses are responsibilities that all Centers have taken on as part of their education mission. In addition, the CRESTs are expanding outreach to involve women, underrepresented minorities, and disabled persons from other institutions in research and education projects relevant to the goals and objectives of the CRESTs. While NSF gives CRESTs flexibility in the type of educational outreach they employ, the Foundation views such outreach as essential if the Nation is to tap into a broader pool of potential engineering talent that traditionally has been underutilized.

The primary role of the education programs in the Centers is the education and training of students, fostering their professional growth in a multidisciplinary environment with team research, industrial interaction, and an integrated engineering systems approach. The education should include practical approaches to engineering as well as theory in order to better serve the needs of industry. As part of the CREST education plan, strategies should

include the active involvement of undergraduate and graduate students in all facets of the Center programs, particularly the team-related research activities. Participation in university-industry collaborative research teams, mentoring of students by industrial researchers, industrial internships, and participation in research seminars are all mechanisms that deepen students' understanding of real-world engineering practices and requirements.

Each Center has a person on the staff or faculty who is responsible for developing and shaping its education programs. The job is referred to by various titles and may occupy various places on the organization chart, depending on the Center. In this chapter we use the title "education coordinator /director."

The following traits/characteristics have been observed in students who have been actively involved in the education programs of an CREST, compared to those who received a non-CREST education. CREST students:

- Have a broad cross-disciplinary education and awareness
- Have a broader outlook, integrate knowledge more readily
- Work better in a collaborative mode
- Have a more global perspective
- Have more effective communication skills, both oral and written
- Benefit from professional conferences and participation in the NSF review process
- Have training in systems-level engineering research
- Are more flexible in resolving research problems by using other disciplines in to help resolve problems
- Have experience in interactions with industry
- Pursue active involvement in team activities
- Tend to seek more research-oriented jobs than non-CREST graduates
- Have a more interdisciplinary perspective on responsibilities
- Need less on-the-job training and are able to contribute to real work earlier in their employment than most other graduates
- Have hands-on experience and are willing to apply hands-on-skills
- Are more sought after by industry, take responsibility and contribute earlier in their careers, and rise to positions of leadership more often.

5-04. Education Program Planning and Direction

In planning an education program, a Center's leadership team must take into account the following:

Center Mission Statement—*A* CREST is a unique organization that has three mandates from NSF: (a) cutting-edge research, (b) technology transfer of the results of the research, and (c) preparation of the next generation of engineers and scientists. The mission statement should recognize the education component of the Center.

Education Program Goals—*P*rogram goals must be specified at the beginning of the planning process. The leadership team, including the Center's overall director, must develop them in conjunction with the director of research, the director of technology transfer, and the education coordinator/director. (All of these functions are known by different titles at different Centers.) This step will ensure integration of research, technology transfer, and education (a hallmark of the CREST Program) and implementation of the program. These goals should be consistent with the mission statement and must address the scope of the program, the mechanisms for integrating Center research and education, and mechanisms for industry-student interactions. The requirements for precollege educational outreach must be taken into account. Because CRESTs have a particular mandate to ensure adequate representation of women and minority students, recruiting measures to meet this mandate must be included. The goals will determine the scope and range of the education program.

Organizational Considerations—Initial planning must include the human resources that will be needed. The director of the education program should be a professional at the same level on the organizational chart as the research and technology transfer directors. It is recommended that a full-time professional be engaged at the outset and included in the planning stages of the program. While some Centers rely on part-time faculty members to serve in this position, employing an individual with an education programming background will allow the Center to implement a complete program.

Strategic Planning—Given the limited lifespan of an CREST, the Center's management must give strategic planning a high priority, beginning in the initial stages of a Center proposal. Strategic plans are dynamic documents that guide allocation of limited resources. They must be revisited annually to ensure that they are able to react to changes in the research and industrial

environment and to allow for the exploitation of opportunities that arise during the year.

Budget—The education program should include resources that match the proposed plan. While supplemental funding (from foundations, NSF, and industry) for particular programs is available, Center resources should be earmarked to support the fundamental components that allow the Center to meet its core educational goals. A typical CREST directly spends $7 million on education and outreach.

NSF/Center Interface—NSF has an important guidance and support role to play in the development and growth of CREST education programs.

5-05. Scope and Range of Education Programs

CRESTs are perhaps unique in their mission to provide an array of education programs across the learning continuum, from precollegiate through collegiate to lifelong learning for postgraduates. It is therefore useful to develop an education program in phases that are implemented over several years. The initial focus must be determined by the education coordinator/director in collaboration with the Center Director and other members of the leadership team.

A phased approach works best. The initial program components would generally comprise curriculum development activities and programs for undergraduate and graduate students. Phase 1a would include course modules and activities for the local college level and precollege students. Phase 1b might include outreach activities for undergraduate and graduate students at other institutions, such as a Research Experiences for Undergraduates (REU) program. Phase 2 might be continuing education activities for practitioners. Phase 3 would include precollegiate outreach activities. It is important to set priorities for these activities in the initial planning stage and obtain consensus among the Center's leadership on the appropriate order of implementation. A mature program that offers programming at all levels, requires significant resources (both human and financial).

5-06. Education Program Direction and Management

Qualifications of the Education Coordinator/Director—To implement a comprehensive education program, serving a variety of constituents, it is

recommended that a full-time administrator be named. Most CRESTs have designated a member of the faculty or senior administrative staff to direct education programs; in several Centers an associate director holds this position. The title for this function varies, reflecting the different administrative structures of different CRESTs. In some Centers with small administrative staffs, one or more existing staff members carry out the functions of education coordinator/director along with their other duties at the Center or in the university, but this approach limits the ability of the Center to offer a wide range of programs. The position should be considered not a support position, but rather a professional position with appropriate professional status.

The choice of education coordinator/director, and the appropriate positioning of this person as a member of the Center's leadership team, will determine the success of the Center's education program. In some Centers, the management believes that this person should have a Ph.D., to elicit the full respect and cooperation of faculty. This is especially important for curriculum development. This question should be considered and resolved at the outset by the Center director and the executive committee. In any case, the primary focus should be on identifying an individual with an appropriate background to be responsible for the education activities of the Center. His or her interest in interacting with students should also be a major selection factor.

Education coordinators/directors are responsible for writing up all aspects of their education programs for the CREST annual report and other documents. They also develop and write grant proposals of many types to expand their education programs. Therefore, strong communications skills and an ability to prepare successful proposals are important.

It is recommended that an education advisory committee be established to give Center faculty a mechanism to provide input into Center education programs and to provide support for them. The composition of this group can include Center faculty, external faculty, and industrial partners as is deemed appropriate.

Strategic Planning—The strategic planning process for education is conducted in different ways at different Centers, with a variety of participants, including the education coordinator/director, the Center director, an education advisory committee and/or the Center administration, and possibly industrial or university involvement.

Some CRESTs involve faculty from all departments of engineering or representatives from industry in the strategic planning process. Knowing the state of the art in your CREST research areas provides a base from which to modify and develop courses. Several CRESTs use the activities of annual report planning and preparation as the time to review education program strategy and make changes. Some CRESTs give the education coordinator/director and staff leeway to make initial plans and decide on strategies, which are then reviewed by the Center director and/or appropriate committee. Other CRESTs form teams consisting of the education coordinator/director, Center director, some faculty members, and sometimes a graduate student representative. Another means of student input is a student advisory committee. Often the membership of such a committee is drawn from the Center's Student Leadership Council (see Chapter 8 of the Best Practices Manual).

CREST education coordinators/directors can consult their counterparts at other CRESTs for ideas in constructing the initial plan, and they can meet with their Center directors, industrial liaison specialists, and senior Center faculty to gather input on CREST education. In addition, the education coordinator/director must become familiar with the curricula at his or her particular school of engineering and other relevant departments within the university. Multi-university CRESTs also must accommodate requirements of their affiliated universities' curricula.

In developing the strategic plan, one should begin by defining the issues of relevance to the particular CREST's vision, mission, and goals.

Initial Planning Issues—Among the issues to be considered in developing and implementing the education plan for a CREST are:

- Development of an education vision and goals (both short-term and long-term) consistent with the Center's strategic plan and objectives
- Identification of the particular populations and student groups to be impacted
- Assessment of resources, both personnel and financial ?
- Development of guidelines for undergraduate and graduate student participation
- Development of a recruitment strategy for undergraduate and graduate students, recognizing that different strategies are required

- Design of an outreach strategy to include K-12, undergraduate, graduate, industry, community, etc., short-term and long-term, which meets NSF and Center goals
- Development of a plan to recruit and retain underrepresented populations in engineering (women, underrepresented minorities, persons with disabilities) in the Center's education and research areas
- Development of a strategy to infuse CREST research findings into the curriculum
- Development of mechanisms to integrate students into all aspects of the Center
- Development of mechanisms for industrial interaction at all student levels, graduate and undergraduate
- Development of a schedule of CREST courses, seminars, and other academic requirements so students can commit to them early in their careers.

Once the strategic plan is developed, it can be used to help write the annual report each year and to plan budget requests and revisions; the plan can be easily reviewed and updated to reflect future progress in the Center.

Overall Goals/Objectives—The first step is to develop a statement of the overall goals/objectives of the education program, keeping in mind the Center's vision (what you want it to be) and mission statement (what you do to implement the vision). Such a statement should include what do you want to do; whom you want to affect, and how you intend to accomplish it. For example, an educational goal/objective might be "to develop and deliver innovative educational initiatives to prepare scientists and engineers for the challenges of the emerging biology based industries, in order to produce a generation of engineers and scientists with a cross-disciplinary team perspective." The strategy to accomplish this goal could include "a major outreach to middle and high school students and teachers."

Initiatives and Actions—Next, one must develop specific initiatives (specific, focused activities) and the actions for carrying them out. (Actions should be stated in measurable terms.) Initiatives might be planned in the areas of precollege outreach, undergraduates, graduate students, lifelong learning, and curriculum development. For example, "K-12 initiatives will provide opportunities for elementary, middle, and high school students and teachers to understand the Center's research field and goals." This initiative might be

supported by actions such as "Maintain a program of yearly demonstrations to X number of schools" and "Develop a web module."

An education strategic plan also should provide for developments over time. A plan appropriate for a CREST in its early years must change as the Center matures, and will change even more as the Center works towards self-sufficiency.

5-07. Graduating Centers: Planning and Preparation

An important issue in strategic planning is the impact of the CREST's five- or ten-year life cycle. Some program components are amenable to institutionalization, but others depend on supplemental funding that is not likely to be continued after funding ends. Courses that have been added to the curriculum by the Center and any associated certificates, minors, and/or majors should be integrated in the university curriculum prior to the end of the Center, thereby becoming part of the continuing programming of the university.

As a Center approaches the end of the cycle, these concerns come into sharper focus. NSF hopes and intends that the culture of CREST education will continue in the Center; but without continuing support from the university and industry, it is likely that most of the CREST's education programs will end. The Center's education coordinator/director should work with the Center leadership to develop a self-sufficiency plan from the outset. This plan can include soliciting education funding from the university, foundations, and the private sector (notably industry).

When a Center "graduates," or reaches its full term, NSF supplemental funding for educational activities may continue on a competitive basis, provided the Center still operates as a CREST. Depending on the financial strength of the graduated Center, some education programs may be cut back or ended. Areas that may be affected include the extensive involvement of undergraduates and underrepresented populations in the education and research activities, as well as outreach programs. The continuation of a graduated Center in some CREST-like form is essential to maintaining support for the associated education programs.

Preliminary data suggest that:

- Research becomes focused on applied, short-term projects that may not be suitable for dissertation-level work.
- Undergraduate research and outreach program components (including programming for minorities and women students) decline.
- Student involvement, interdisciplinary focus, and team-based research decline.
- In most universities with graduated Centers, the main lasting effect of the NSF CREST funding is the development of multidisciplinary degrees, minors, and certificates that have helped shift engineering education away from the traditional disciplinary compartmentalization toward the interdisciplinary focus that is required to solve today's STEM challenges.
- Studies and a recent survey of graduated Centers have shown that successful continuation of education programming depends on several factors:
- A full time (hard money) person to coordinate activities, who is prepared to seek funding from grants and other sources
- Strong institutional support, including support for the CREST education culture as well as significant cash or other direct financial assistance; finding champions of the education and preparation of students, both in industry and at the university level, is critical
- Faculty motivated to continue and institutional incentives that further this motivation
- A strong, continuing commitment on the part of Center leadership to the goals of an CREST education program
- Successful securing of funding from governmental agencies and foundations
- Creative ways of packaging program elements that fit the type of activities industry is able and willing to support (i.e., lab training internships, design course support, graduate fellowships).
- A strong, evolving research program.

Attention must be paid to all these characteristics from the outset. They must be nurtured and maintained throughout the life of the Center, to provide a platform for successful implementation of the strategic plan.

5-08. Developing a Budget

The budget of an education program depends on many factors, including the education plans of the Center, the expected industrial involvement, the number and type of NSF supplemental funds granted, and the initiative of the education coordinator/director. The size and complexity of the program will depend on the commitment of the Center's leadership to the education program and the priorities set during the initial planning stages.

Items that should be in the education budget include:

- Administrative costs (such as the education coordinator/director's time, support staff, printing, and data management)
- Graduate student support
- Funding to support the undergraduate research program
- Funding for precollege outreach
- Travel (for recruiting, dissemination, and so on).

The initial budget for education should include funding for start-up, advertising and recruiting, and other efforts to ensure a successful beginning for the program in addition to stipends for undergraduate students (for Center research fellows, summer research programs, and other activities), research assistantships for graduate students, and appropriate staff support. Because CREST education programs must make extensive reports to NSF, data management capabilities must be planned for at the outset.

The initial budget may include some costs (such as travel) that support the development of relationships with other undergraduate and minority institutions. Once these relationships have been developed, budgets may be partially reallocated to other purposes. Some Centers use education budgets only for stipends and student support, with staff and travel budgeted in other Center funds.

Dissemination is an important part of an education program. There are many opportunities for STEM educators to learn from each other via regional and national conferences. Travel funds should be provided to allow faculty, administrators and students to participate in these meetings and organizations.

As the Center matures, NSF supplemental funding and leveraged support from other sources, as well as industrial funding, should increase.

As the Center approaches graduation, the most likely scenario for continuation of the education programs is through leveraged support via additional funds from the university, foundations, industry, or state programs as well as NSF/CREST education programs.

Education budget decisions allocating overall resources should be made by the Center leadership-including the director, education coordinator/director, research director, and industrial program director-serving as an executive committee.

Faculty attitudes toward Center education programs differ with respect to funding. A research faculty member who is also coordinating an education program commented, "It is clear that faculty respond to rewards (primarily funding). If money is allocated primarily on the basis of research, then there is little incentive for faculty to devote significant effort to developing new or innovative educational activities." At many CRESTs, however, faculty are enthusiastic about the education programs and even offer to support additional students from their research funds.

Adequate baseline funding must be provided to the program, however. A collection of supplemental grants alone does not make a coherent program, as not all funding opportunities will fit in the education strategic plan and only those that do fit should be pursued.

Some further tips:

- Be aware of the financial environment of your industrial partners. Check with them to see if their budgets are based on the "use it or lose it" system. If so, they may be able to donate funds during the last quarter of the company's fiscal year. Continuing education programs for industry can be self-supporting and/or generate funds by pricing short courses properly. Surveying the Center's industrial partners will help determine if this is an option for a given Center. Written educational materials

developed for either practitioners or students can also be sold at cost to cover the production for the materials.

- Flexibility in budgeting is extremely important. The ability to fund an opportunity when it arises is essential if the Center is to benefit from such opportunities. It is useful if there is a discretionary pool of funds in the Center for capitalizing on education as well as research opportunities. It is also important to know what educational expenses the departments and universities can help defray. Tuition remission, possible use of non-overhead accounts for educational programs, university scholarships or fellowships, existing education programs that might provide matching funds, appointments as a teaching assistant for a semester-all these can help augment the education budget. Check with the Student Affairs or Minority Affairs Offices for possible Fellowship Programs. Not only will the students gain prestige and invaluable contacts if awarded such fellowships but the Center's budget will benefit as well. Centers should work with campus and college foundation offices to identify sources of potential funding and to coordinate their efforts. Also check your other funding sources to see if there is supplemental funding available under their programs. An example is the possibility for funding for minority students on NIH individual investigator grants.

- Be sure to market your successful educational programs to your universities, your industrial stakeholders, and others outside. The resulting positive publicity may attract volunteers and other support or help recruit students. Publicity of Center programs also promotes the concept of the CREST.

- While it is understood that a portion of the Center budget should be devoted to educational activities, there appears to be a tendency across the CRESTs to make the direct education allocation (i.e., exclusive of graduate student support) relatively small. Such an approach leads to difficulties in developing a strong education program and meeting NSF's goals for CRESTs. It is helpful to understand that there are more demands for programs but usually there aren't additional funds allocated. Therefore, attention must be given to developing strategies to fund these programs and increasing the effectiveness and efficiency of the use of resources for the educational area.

- Funding and staffing for the education program should be consistent with its high priority among NSF's goals for the CREST program. Some Centers

have found that administering a truly comprehensive program requires two professional staff, with an education coordinator in addition to an education director. Support staff must be provided to the education programs as required, depending on the overall size of the Center's administrative support staff and the breadth of the education programs. Part-time support for specific activities can usually be arranged using existing staff or student workers. The staff requirements should be a function of the programs being offered and the associated resources.

- It is difficult to specify the amount of staff time required and the level of funding, because these are dependent upon the education goals and objectives of the Center as well as the level and breadth of programs offered, the age of the Center, and other factors. However, an under-funded program will have difficulty meeting the CREST education mandate.

5-09. The Role of NSF

CREST program staff are most obliging in helping the CREST education coordinators/directors develop and enhance their education programs. They have the experience to provide guidance and identify others who might serve as resources to assist in strengthening the education programs. NSF also provides publicity to industry and works through other NSF programs to support the Centers.

Some examples of NSF's aid to CREST education programs are these:

By continually stressing the importance of education and educational programs in the CREST, NSF program directors and officials emphasize to the leadership and faculty of the CREST the significance of these programs. This greatly helps the education endeavors at the Centers.

- NSF provides opportunities for additional sources of funding and publicizes these funding options to the Centers.

- NSF provides the supporting framework for coordination between Centers.

- NSF realizes the significance of collaboration between Centers and encourages these collaborations verbally and through funding sources.

- NSF provides critical insight to our Centers through the annual site visits that help improve Center programming.
- NSF provides guidelines that define the programs from the inception of the Center to the reporting guidelines that document annual progress.

By mandating an industrial component to the Center's architecture, NSF has laid the groundwork for the development of education programs with a strong industrial element, benefiting undergraduate and graduate students.

By funding the CREST Centers, NSF is promoting innovative programs that allow cutting-edge technology to be developed to the point where it can be utilized by industry and benefit the general population. Center education programs are an essential vehicle for disseminating these new technologies into industry, by means of the Center graduates and outreach.

A strong relationship with the NSF CREST Program Leadership, and especially the Center's NSF Program Director, will enhance the development and implementation of an CREST education program.

5-10. Education Programs

CREST education programs have evolved displaying many common features that have been shown over time to work in the CREST culture. At the same time, there is great diversity of program elements, reflecting the Centers' differing missions and their organizational relationships with specific universities, industries, and professional fields. These differences occur both in the details and in the attributes designed to address the individuality of each CREST in its particular university, field, and industrial base. This section describes both the shared and distinctive features of those programs.

Cross-Disciplinary Systems—CRESTs view the cross-disciplinary nature of their education programs as an attraction for students. All CRESTs have cross-disciplinary missions, and most have students and advisors from many departments. Other Centers have been equally creative, developing courses combining engineering and sciences.

Teamwork—Teamwork experience is vital to engineering students. CRESTs' industrial partners are generally impressed with the maturity and team preparedness of the graduates, who have had more industrial interaction than the average STEM graduate.

Involvement of Industry in Education—Several CRESTs encourage students to have industry advisors on their thesis committees. This supplement to traditional academic mentoring gives graduate students a valuable perspective on industry's concerns and gives them a head start on careers in industry. In addition, most CRESTs require or suggest an industrial internship for each student, to acquaint him or her with real industrial problems. Such an opportunity provides the student with a chance not only to become familiar with industrial work, but also to receive an offer of permanent employment after graduation.

Communications Training and Opportunities—Student researchers make many of the presentations at Center reviews, and many have more opportunities to travel to conferences to present papers or posters than the average graduate student.

Mentoring Opportunities—Many CRESTs provide opportunities in which graduate students work on teams with younger students or are chosen to act as mentors on special projects.

Exposure to the Latest Developments—Students are able to stay on the cutting edge through increased travel opportunities to conferences, visiting scientists programs, seminars, and annual student conferences.

Research is the main direct educational mechanism by which graduate students interact with the CRESTs. It has been said that the distinction between research and education is not really valid at a CREST; the two activities overlap and interact at many points. Graduate students work under the supervision of one or more faculty members associated with the Center in an area related to one of the Center's research thrusts. Most of the Centers ensure that the research projects are cross-disciplinary in nature and conducted with a spirit of teamwork.

The goal is to have CREST graduates be adept at this systems-level, cross-disciplinary team approach to problem solving. They should understand and share industrial perspectives and be well prepared to contribute immediately and productively to jobs in industry.

5-11. Recruitment

Because the Centers must be ever mindful of the relationship between them and the associated departments and colleges, recruitment must follow the

application procedures of the student's potential department/college first. However, once the student has been accepted in an academic program, probably the two most influential means of attracting students to the Centers are word of mouth and the Center's Internet presence. Faculty and staff should involve themselves in department/college programs (such as the admissions committees) to be aware of newly available students. Center personnel should keep a network of contacts in department or college recruiting offices (particularly special offices for women or minorities) who have regular interaction with students. Invite those contacts to presentations about the Center. If these individuals are familiar with the Center's program, they are more likely to steer promising students that way. Students and faculty traveling to conferences should be provided with brochures or fliers to spread information about the Center. The Center's Web site (particularly student opportunities) should be updated regularly and often. Finding an application on the Web site with a due date that is two years past is most discouraging. Also, keep in mind that even the most engaging Web site is still a very passive means of outreach—find new, proactive ways to attract students and employers to the Center’s activities.

Another venue for recruiting is on-campus chapters of national organizations-and the annual national meetings of these organizations. Again, make information available at such meetings. Advertising of special financial incentives may also be used.

5-12. Student Financial Support

Most graduate students are supported financially by the Center. Others are supported from other funding generated, often, by the CREST or faculty involved. CRESTs are creative in covering the costs of graduate education through industry contracts, NSF grants, foundation or corporate scholarships, other federal and state agency sources of support, and industrial partner support for graduate students.

CRESTs also encourage graduate students to apply for professional society or industry scholarships, or in some cases prepare proposals and perform contract research for funding to pay for conferences and research. Successful proposals allow graduate students to travel to conferences and companies.

One of the goals of CRESTs is to provide global leadership not only in the Center's research areas, but in education programs as well. To fulfill this goal, most CRESTs developed education programs involving other

universities, professional organizations, or industry. The focus of such activities is on educating and training faculty and students in other institutions and establishing long-lived collaborations.

Many CRESTs provide opportunities for faculty and doctoral students from other countries to conduct research and gain experience, generally by hosting the visitors for one- to three-month visits. Such programs offer valuable chances for collaboration and enhance the visitors' research. Some of these CRESTs have established international internship programs, augmenting financing of students from international institutes. Others have established exchange programs with foreign institutions. As a result of such partnerships, faculty from the participating institutions direct research and teach courses at each other's university. Such programs also permit CREST students to take courses in the international institution and their students to study at the CREST.

5-13. Undergraduate Programs

Integrating undergraduate students in the educational activities of CRESTs is mandatory, and perhaps the single most innovative aspect of the CREST education program. While the research focus and educational vision of CRESTs may differ, active involvement of the undergraduates has a major impact, not only on their education, but also on those around them. A special feature of the CREST Program is the emphasis on undergraduate participation in research. Each of the CRESTs has one or more programs through which undergraduates from the Center's home institution(s) engage in research projects. Many also involve undergraduates from other institutions in CREST research activities through the CREST Program's competitive Research Experiences for Undergraduates (REU) program.

Most CRESTs have at least 15 to 20 undergraduate participants involved in research programs during the academic year. Across all of the CRESTs, the ratio of graduate to undergraduate students is 2:1. Some have exceeded that goal. These undergraduate programs share several features. Students come from any of the departments that relate to the Center's work and are selected from among the best students. Generally, each student works with a designated faculty member and, under his or her supervision, conducts research with one or more graduate student mentors, receiving academic credit and/or a stipend for the work. In some Centers, students may use

their CREST-sponsored research as a basis for a senior honors thesis or independent study course.

Undergraduates may be recruited through presentations at student organizations such as the student chapters of professional societies. They may also be recruited through announcements in the student newspaper, the CREST's Web site, printed flyers, and directly from classes and colleague's recommendations. Also, deans and departmental and other university offices may be helpful.

5-14. Community Colleges and Technical Institutes

The nation's community colleges and technical institutes are valuable and often underused sources of technical workers. Community colleges serve a vast number and diverse population of students. For example, in Maryland between 40% and 60% of students in post-secondary education are at community colleges. Due to the flexible scheduling, modest cost, and other reasons, community colleges attract large numbers of women and minority students. It is estimated that half of the Hispanic students attending college nationwide are at community colleges.

In addition, many community colleges have historically close ties with industry. Industry-oriented or industry-sponsored certificate courses and technical training programs are often associated with community colleges rather than four-year colleges. Despite this obvious connection with the CREST technology infrastructure, very few CREST programs have actively focused on creating links with community colleges. We are aware of only four CRESTs that have made substantial partnerships with community colleges or technical institutes. It may be that community college efforts, falling in the gap between education on the cutting edge of new technology and outreach effort to the K-12 pipeline, simply offer less obvious benefit to the CREST universities. It is also possible that, because of an emphasis on continued technological innovation, few CRESTs have developed to the stage of a mature technology where training programs are an industrial priority.

5-15. Precollege Outreach

It is widely recognized that much of the difficulty of recruiting enough well-prepared students into STEM programs is a "pathways" problem, the roots of which lie farther back along the educational path than the freshman year,

reaching into high school and even earlier academic experience. CREST K-12 outreach programs are focused at helping fill that pipeline with prepared and motivated students. However, no CREST can be all things to all constituencies. Each CREST should determine what precollege offerings make sense in the context of its strategic plan, resources, and community relationships. Some suggestions for achieving successful outreach can be drawn from experience:

- To make the best use of limited resources for CRESTs' precollege outreach, many CRESTs work in partnership with other education and outreach programs. For maximum impact, it is best to seek out established programs to which CRESTs can add significant value, or to find promising new endeavors with which to partner.
- To encourage program diversity, it is useful to partner wherever possible with established campus multicultural programs. Engineering colleges normally have offices responsible for multicultural programs and recruiting.
- To have successful outreach programs in multi-university Centers, it is best to have a professor, staff member or student responsible for the outreach program at each participating location. Programs can be administered from a central location, but an on-site representative on each campus is desirable. Forming an education committee or thrust with a representative from each campus can be valuable in accomplishing this goal.

5-16. Outreach to Students

Student Camps and Courses—Many CRESTs have sponsored student camps and courses to involve K-12 students in fun, hands-on science experiences and thereby interest them in technology and careers in science, mathematics, and engineering. Summer camps are particularly popular as programs targeted at minority students. To develop and implement such programs requires a significant commitment of administrative and research staff time and resources.

Research Experiences for Students—Most CRESTs also offer summer research programs or internships for K-12 students. The purpose is to get students into research labs early in their careers, to excite an interest in research and in science or engineering careers. These programs can require significant effort from administrative and research staff. They generally involve Center graduate students, too.

Student Competitions—Several CRESTs sponsor student technology competitions or science fairs. Often this is done by involving Center researchers and graduate students as well as local partner organizations. The purpose is to involve students early in exciting science projects and research, or in fairs and exhibits displaying interesting and topical research.

Student Tours and Visits—Another way to involve local K-12 students and teachers in CREST research is to offer tours to school groups, or to send CREST students into local schools to demonstrate and discuss their research. These tours and visits may require slightly less organizational time than organizing student camps or internships. Most CRESTs offer student tours, but only a few offer school visits.

Public Lectures—Public lectures offer opportunities to participate in ongoing outreach efforts can be easy ways for CRESTs to reach out to communities.

5-17. Outreach to Teachers

Conferences and Workshops—Several CRESTs offer teacher conferences and workshops. Many CRESTs feel that it is possible to multiply their efforts and reach more K-12 students by increasing teacher interest and knowledge in science and engineering, particularly exciting new research. Organizing these conferences can also require significant amounts of administrative and research staff effort. Participating in an existing conference requires less effort.

Research Experiences for Teachers—Some CRESTs offer research internships or experiences for teachers during the summer months. Again, the purpose of all such programs is to excite and revitalize teachers by providing them with knowledge of cutting-edge research. Some of these programs require teachers to write new lesson plans based on their research experiences. Planning these experiences can require significant amounts of both administrative and research staff time. Graduate student researchers will need to be heavily involved.

Development of Teaching Kits and Aids—Some CRESTs have developed curricular materials for teachers based on their research expertise. This approach requires some knowledge of secondary curricular development as well as subject expertise. Partnerships with colleges of education or use of education students may be appropriate.

5-18. Curriculum Development

Mounting a successful application to NSF to establish a CREST is a major undertaking, requiring substantial coordination of many faculty from different disciplines. The faculty involved in developing the CREST may already have a vision for new interdisciplinary courses or even a new degree program, and the CREST can help solidify the interactions that lead to course development and administration.

The role of the CREST is that of a catalyst; the resources provided by NSF are relatively small compared to those needed to develop and maintain an entire academic program. Still, the catalyst serves an essential role, and there are examples of CREST programs that have provided the necessary impetus for creation of new degree programs. Degree programs may start as minor degrees, specializations, concentrations, or certificate programs and then evolve into new BS degree programs as the academic infrastructure grows through addition of resources from outside the CREST.

The role the CREST plays in developing new degree programs at an institution depends strongly on how intellectually developed the field already is at the time the CREST is funded. If the area is new and just evolving, the CREST may lay the foundation for development of a program that comes to fruition after the graduation of the CREST from NSF support. If the CREST is funded in an area where faculty members are already offering interdisciplinary courses, a degree program may evolve more quickly.

New degree programs require substantial long-term institutional resources and commitment. Institutions have a responsibility to ensure that students are well prepared for life after the degree, and thus typically want extensive intellectual justification for how new programs will allow students to adapt to jobs in industry or academia. A very important role of the CREST in the evolution of new degree programs is to stimulate the development of new courses, particularly interdisciplinary courses. These courses may provide the intellectual basis for a new degree program.

Finally, in addition to a formal curriculum, CREST staff can help with professional development of students by serving as sponsoring administrative units for undergraduate professional society activities, providing essential links to industry contacts, and helping arrange seminars and company visits.

5-19. New and Modified Courses

Developing new courses is the first step toward integrating the CREST research objectives into the formal education process. The philosophical and administrative aspects of course development vary widely from institution to institution. At some institutions it may be possible for an CREST staff member to serve as the prime mover. At other institutions, faculty members serve in this role. Ultimately, the university is responsible for paying faculty to teach the course, and for providing additional infrastructure if the course is a lab subject. Thus, courses must fit the overall educational objectives of the degree programs at the institution.

CREST nonfaculty staff, in developing undergraduate and graduate courses, should find the following tips helpful:

- Find an interested professor to be a champion for developing the new course.
- Pay the professor and a student helper to develop the course; or arrange with the professor's department chairperson to give the professor given teaching reduction so that he/she can develop the new course.
- Beta test course materials.
- Work on mechanisms to offer credit for students to take the course at other CREST universities if your CREST is a multi-university Center.
- Find a vehicle, such as CD, web, or book, for wider distribution of course materials.

In institutions where CREST faculty bear this responsibility, faculty can take advantage of these suggestions, which build on years of hands-on experience:

- Discuss your idea for a new course with your department head or undergraduate curriculum committee. If the new course is an elective in a hot field and you can demonstrate that students will flock to this course, the department will likely be supportive of your plans to develop it. For untenured faculty, development of a signature course can be a very positive factor in your promotion case.
- If preliminary discussions are positive, determine whether you will be provided with long-term support for teaching the subject. Developing a new course requires a great deal of work, so one should make sure it can be taught several times.

- Find a mechanism for supporting your time in developing the course, and for providing appropriate support, such as teaching assistants. If there is no textbook available (likely), course development requires a substantially greater investment of time than teaching an established course does. Foundation and government grants are available for new course development, and can be identified by asking colleagues.

5-20 New Degree Programs

Minor degrees—Minor degrees give students the opportunity to develop depth in areas outside their major programs. The rules for offering minors, as well as student participation in minor programs, vary widely from institution to institution. At some schools interdisciplinary minors are a means to evolve the curriculum toward a new undergraduate major by providing a testbed for courses and development of student professional societies; other schools are not geared toward interdisciplinary minors. If the Center is in a cutting-edge research area, and students are excited about a minor degree in the area, chances are it can develop a successful minor even if there are institutional barriers. The key is to build on student interest and enthusiasm. Here are some important considerations:

- The first step is to define the intellectual content of your minor-what is essential for students to learn, and how many subjects are required? Are there subjects already offered that could fit the minor, or do you need to develop several new courses?
- Determine which academic unit is the best home for the minor, whether a single department, a pair of departments, a school or college, or the whole university. An academic unit will be required to handle the administrative details if the minor appears as a degree designation, and the academic unit involved needs to be extremely supportive of the minor.
- The easiest minor to develop is for students from one's own school (e.g., engineering), because those students are likely to have taken the prerequisites (e.g., mathematics, programming skills, and biology) needed to take the more advanced courses in your minor. (Some academic institutions have firm requirements that any student should be able to complete any minor, and one must be cognizant of what your institution requires.)
- If one develops a minor for a diverse student audience (e.g., including both science and engineering majors), it is helpful to define a set of preparatory engineering subjects that provide the necessary background. For example, non-engineering students may need to take differential equations and a mainstream sophomore level engineering

subject that uses differential equations to solve physicochemical engineering problems before they can enroll in the subjects in your minor. Alternatively, courses can be developed for non-majors, but this is usually a less attractive option over the long term. Engineering faculty are generally reluctant to develop a course for students who do not have engineering backgrounds, and cannot justify teaching such courses when teaching assignments are made.

- The minor should be well coordinated with the curricula of the major degrees. One must put appropriate advising in place to ensure that students are able to plan early in their academic careers to fit all the minor subjects into their schedules. It is helpful, for example, to write up a special advising document for freshmen and sophomores, to ensure they take appropriate background subjects early on. Conduct advising seminars once per term to get the word out to a broad audience.

- A minor degree curriculum, no matter how well planned, does eat into the unrestricted electives available to students. Some students may even overload on subjects in order to complete the minor. It is thus especially important to have good advising-students must appreciate that the minor is in some sense an honors program if it requires substantial technical work. It is a choice the student makes. Students who are weaker academic performers might be encouraged to focus on their majors first.

- Create a curriculum committee that meets regularly to review the content and administration of the minor, and invite all the advisors for the minor to serve on the committee.

- Create a community of students involved in the minor by having lunches with students and faculty once per term.

BS Programs—New bachelor's degree programs must be developed with a different set of considerations in mind:

- Find out what new degree program in engineering or science was most recently approved at your institution, and use that program as a benchmark. Some institutions are conservative and develop new degree programs only once every few decades in response to new disciplines.

- The faculty who teach the courses and who will be responsible for the degree program after the Center's NSF funding expires must be key drivers in developing the new degree program. Be sure to get the support of key faculty members, who can provide sustained efforts to convince the chair, provost, curricular committees, and other decision makers.

- Identify the constituencies for your program, and make sure you have enthusiastic buy-in. Equally important, identify any other academic programs that will be significantly affected (positively or negatively) and discuss your plans with the faculty involved. For example, if you are developing a program that depends on core science classes offered by another academic unit (such as chemistry, math, or physics), they need to be involved if their enrollments are likely to increase as a result of your plans.

- Make sure to contact your university's appropriate office (e.g., the provost) to find out whether prior approval is required for a new undergraduate degree program. There is no point in developing an entire program if it will not pass this first hurdle.

- Work as closely as possible with the chairperson of your school's curriculum review/approval committee, as well as your university's undergraduate curriculum committee, before submitting all of the paperwork to those committees, to be sure that they buy into your new program. Doing so can save a lot of time in getting your new program approved, because these committees frequently deny or delay approval because of incomplete forms or unclear descriptions.

- Involve undergraduates in developing the new curriculum, to understand their interests and needs from the outset. This can be accomplished by presenting a proposed curriculum at a meeting of the professional society for the area related to the program. Some universities require participation by undergraduate students during the development and evaluation stages of your new program. Neglecting undergraduate input can cause very long delays in getting the new program approved.

- Be sure that your program satisfies criteria of the Accreditation Board for Engineering and Technology (ABET), if one of your goals is to have an accredited program. Review and update this program on a regular basis.

MS Programs—New master's programs present their own challenges. These suggestions should ease the labor of developing one:

- The easiest MS programs to develop are those that build upon an existing traditional MS degree. They do so by adding an area of emphasis to the existing program, e.g., MSEE (Multimedia and Creative Technologies). Be sure to get departmental buy-in from the beginning of the development process for this kind of new MS program, because you will be tinkering with an existing departmental program.

- Include opportunities for students to do some directed research with CREST faculty and to receive credit for it. The uniqueness of your

CREST will permit students to do directed research with CREST faculty. This can be a valuable selling feature for the program.

- To break down the barriers of existing traditional MS degree programs-which all have specific requirements that may be viewed as barriers-one usually must create a new degree program.
- If you do create a new degree program, you must also find an administrative home for it. Do not underestimate the importance of this requirement, because it has budget implications to the unit that accepts this new responsibility (e. g., a person must be identified to administer the program, space may be needed for student files, etc.).
- Be sure to have a group of faculty willing and ready to advise students for your MS program(s).
- One model for a practice-oriented MS program is a three-component program that includes (a) an engineering component, (b) a management and business component, and (c) an internship program. Students who complete the engineering component could also receive a certificate (e.g., in Microelectronic Packaging).
- Review and update these programs regularly.

Professional Certificate Programs—New professional certificate programs will be more effective if their developers follow the following suggestions:

- Conduct market surveys to evaluate industry interest and demand for short courses and topics.
- Advertise the short courses in trade publications and with mass mailings. Purchase mailing lists.
- Find commercial and industrial partners to co-sponsor courses.
- Use your Center's industrial advisory board to champion and publicize offerings.
- A very effective way to reduce expenses is to offer short courses at conferences.
- Anticipate economic downturns (during which too few students may sign up to offer the course); demand for short courses is highly variable.
- Pay professors to offer (develop, organize, and teach) short courses.
- Seriously consider using the internet to deliver the short course. Such courses could be recorded and made available on demand.

- A certificate (given to a student for completing a certificate program) avoids some of the problems encountered with official degrees and can serve a Center's objectives for recognition of its involvement and professional certification.
- Professional certificate programs should be created if they enhance the visibility of the Center and make real contributions to the engineering profession.
- Short courses and certificate programs may be created based on a sound understanding of current professional demands, especially as they pertain to licensure issues.
- Certificate programs may be structured as terminal programs (which will not undermine the efforts of the department to draw students into graduate programs), or they could be given upon completion of part of a degree program.
- The developers of a short course or a certificate program should also look at pre-existing certificate programs offered by other departments or schools to see how they complement one another. If competition exists, it will be necessary to identify champions within the respective departments, and to develop a cooperative relationship so that each department sees a benefit from the program.

5-21. Center/Department/College Curriculum Relationships

Non-faculty CREST staff should bear in mind the organizational relationships of academic units:

- Assure department chairs that your CREST is not an academic unit, so that your Center is not competing with it for tuition revenue. (This may not be an issue at some universities.) NSF strongly encourages Centers to develop new academic programs that reside in some department (or departments).
- Keep the department chair (and education associate chair, or faculty and administrators) in whose department the new program will reside aware of your plans. They will have to approve the program, so the program should not come as a surprise to them, especially since the new program will most likely mean additional work for departmental student affairs personnel, and may require some budget to administer.
- If your new program will require departmental resources (e.g., space, equipment, teaching assistants), involve someone from the administrative staff of the department hosting the new program as part of the development of the program, so that resource issues can be adequately addressed. In most CRESTs, staff, and increasingly students, carry out the outreach functions.

- The basic concept should be to use NSF money as seed funds to help departments establish new courses or programs-not the other way around. The challenge is to convince the majority of the faculty members that the effort is worthwhile and will benefit them and the department.
- Keep in touch with the participating school chairs, undergraduate and graduate education committee chairs, and graduate coordinators.

5-22. Educational Outreach to Industry & Communities

Educational outreach efforts for a CREST must be designed to reach industry as well as the wider community. This section explores these topics, with examples featuring successful and original approaches and suggestions.

The Center's relationship with its partners in industry is crucial and direct. Through it the CREST gains by learning about industrial perspectives, practices and needs, which it can then incorporate in education and research. Industry gains by learning about new research and technology, by direct interaction with students (the best channel of technology transfer), and by the opportunity to work with and recruit highly trained CREST students and graduates. Industry and CRESTs must cooperate closely to tailor programs that meet the interests and needs of the students, faculty, and industrial members of the CREST. The education coordinators/directors should keep abreast of industry programs in detail, and of trends and particular requirements and developments in the relevant industries.

The industry-education link has several goals. The process of learning in this relationship is a mutual one, in which the CREST and industry serve alternately as teacher and learner. Education programs provide opportunities for student-industry and faculty-industry interaction via mentoring, internships, co-advising on theses and doctoral programs, recruitment, employment, visiting scientist programs, seminars, workshops, and presentations. Industry may directly sponsor education programs or educational innovations relevant to industry needs and goals. As part of the lifelong learning aspect of their education programs, CRESTs also sponsor seminars, workshops, and short courses to bring industry to the Center (or take the CREST to industry), transfer technology and CREST research to industry, and encourage faculty exchanges with industry. Certificate programs are an increasingly useful way to bring industry to the CREST (and take the CREST to industry). Many CRESTs use distance learning to link both multiple CREST institutions and industry partners.

Special community outreach programs aimed at specific groups can enrich the diversity and extend the impact of the CREST. Examples of such programs are those targeting at-risk groups, such as high school students or high school dropouts, or targeting dislocated workers via retraining programs, or targeting technical students via community college programs. Continuing education programs are also relevant for the wider community audience and the general public, as well as for academia. Educating the public about the value and meaning of engineering and science in daily life is a role that CREST education programs must increasingly address.

The CREST's education coordinator/director should have a close relationship with its industrial liaison officer, because the two activities overlap strongly and affect each other's results. The education programs should serve as student advocate, and the industry program as advocate for industry. Developing common goals and a relationship that ensures joint input into programs is essential to a strong education program that is relevant to industry and meets industry's demands and needs. The CREST director must aim to meet industrial needs while ensuring that CREST educational programs meet student needs, degree requirements, and educational goals.

The value of the industry-education link to CREST success and CREST sustainability cannot be overemphasized. The link between industry and education is one of the determining factors in the success of an CREST, and the strength of this link is a crucial element in the longevity of the Center. It can also provide a strong base for a successful sustainability plan, and this element should be incorporated into CREST strategic plans at an early stage of the Center.

5-23. Student/Industry Involvement

Industry is involved in all aspects of the CREST education program. Industry representatives may serve as mentors to undergraduate, outreach, or graduate students. They may present lectures, course sections, or entire courses, or teach courses in partnership with CREST faculty members. Industry experts may serve on the student's masters or doctoral committee. Industry may sponsor undergraduate or graduate internships in industry, or sponsor students' undergraduate or graduate degrees in whole or in part. Industry input will help shape curriculum, develop original courses, and shape the very nature and approach of the engineering curriculum of the future. Industrial representatives may serve on review panels evaluating and

shaping the CREST education program. Industry interaction with CRESTs may result in new employment and internship opportunities for students, and even lead to the development of new research projects and thrusts for the CREST.

Many creative approaches have been developed to strengthen the link between industry and students in the CREST program and provide opportunities for industry to mentor students. Teams of students and faculty may travel to companies for presentations, meetings, and tours. Industry also may design projects or suggest problems for study by a team of students in the CREST.

Education coordinators/directors may provide advice on the structure of industry participation, and may suggest changes in the plan as an CREST matures. One important issue is the nature and amount of student interaction that corresponds with various levels of the membership structure (since industry often comments that CREST students are the most important product of the CREST.) As the CREST grows, balancing supply and demand can prove challenging. The education coordinator/director may wish to consult with the education coordinators/directors and industrial liaisons at other CRESTs regarding these issues of balancing industry demand for students with the CREST's ability to supply them.

One of the most valuable mechanisms of industry-education interaction is the student internship experience, in which the student is sent to the industry site. The student may be an undergraduate, an outreach student such as a Research Experiences for Undergraduate fellow, or a graduate student. The industrial internship formalizes industrial collaboration and ensures that the fellows' education prepares them to contribute effectively upon graduation. The student gains from exposure to the real world of industrial product development and access to industrial researchers, and the company benefits from direct access to the student/technology inventor. There is no better mechanism for technology transfer than this direct personal contact. Industrial advisors of these interns commonly report innovative products, shortened development cycles, leveraging of industry resources, and joint research projects. This experience also has several benefits for the student. The relationship with an industry engineer provides a unique and essential educational experience. Work in an industrial environment provides the base for a student's career in industry or academia, enables him/her to experience a team/systems approach to research and development, and cements

professional relationships. This process also extends the influence of the CREST into the industrial sector.

Almost all CRESTs offer or require a graduate student internship experience, ranging from a few weeks to six months or longer, as part of the student's predoctoral experience. Every CREST reports that the industry internship is enthusiastically received by industry. It gives companies the opportunity temporarily to employ students who are highly trained in new technologies, and also offers recruitment opportunities for longer-term employment at a reasonable cost. For students, internships give training in industrial methods and approaches. Students learn to work with industry, to present and defend their work in a professional way, to work in teams, and to set and meet goals and timetables. Many Centers require internships as part of students' doctoral programs. Some Centers offer industry an opportunity to support the doctoral candidate for a fellowship. To ensure that students meet their degree requirements and to help the industrial internship mesh with the CREST's education goals, the education coordinator/director and staff should work with each student's major department and degree-granting school or unit, and with the CREST's industrial liaison, to coordinate the industry internship. In addition, he or she must work with housing, relocation, travel, and payment staff to ensure the student's safety and comfort (particularly important for students with disabilities), and help smooth the transition from internship to school and back. Proper handling of these practical details will avoid disruption and ensure enthusiastic student involvement.

Industrial interactions involving undergraduates, while less common, provide important opportunities for younger students to gain perspective on industry. These students often have considerable creativity and energy to offer industry, in lieu of experience. Some creative approaches to industry-undergraduate interactions involve class projects, team approaches, and co-op education.

Industry involvement in education can also include "outreach undergraduates," who are not from the CREST's home institution. For example, at the Center for Advanced Engineering Fibers and Films at Clemson University, industry members jointly develop Research Experiences for Undergraduate (REU) projects and co-advise students.

To attract industry membership and support, every CREST actively promotes the possibility that industry sponsors can recruit CREST graduates. CREST graduates are sought after by industry; industry surveys show that

graduates are 18 months to two years ahead of the traditional engineering graduates in job skills and experience. The opportunity to recruit CREST outreach, undergraduate, masters, or doctoral students is the strongest force to keep industry involved in CREST education programs.

Another curriculum approach is to develop and present industrially relevant classroom projects, which can include smaller team projects in a projects class, or whole classes devoted to a specific project. Industry may design the project or present a problem for CREST researchers to tackle.

A visiting scientist or industry researcher on campus program can provide intensive, longer-term industry-student interaction. The industry scientist may divide his or her time between the research laboratory and teaching duties in the laboratory or the classroom. He or she may also serve as a student mentor or a member of a thesis or doctoral committee. Many CRESTs have programs for visiting scientists under various names. For example, the Packaging Research Center of Georgia Tech has an "engineer on campus" program, and the Biotechnology Process Engineering Center at MIT offered a "visiting scientist sabbatical." The value of an industry representative on site at the CREST makes the effort to arrange these visiting scientists' tenures on campus well worth the effort to the CREST.

Visiting scientist programs must include mechanisms for determining and handling administrative details such as salaries, responsibilities, and payments; relocation expenses and issues; housing and family placement; office space; computer access; and university privileges such as parking and athletic facilities. Additional issues (such as visas) apply to visiting scientists from foreign countries.

5-24. Seminars and Workshops

CRESTs' education programs, like their industrial programs, promote faculty exchanges with companies via visits, seminar series, workshops, degree and certificate programs offered on campus or at industry sites, or in professional meetings and events attended by CREST faculty and relevant industries. Every CREST holds an industry meeting at least annually, and this meeting is an important arena for faculty-industry and industry-student exchanges at poster sessions, meetings, and panels. (See Chapter 5 of the CREST Best Practices Manual, "Industrial Collaboration and Technology Transfer.")

Seminars and workshops are among the quickest, most efficient, and most economical ways to promote industry-CREST interaction involving students and faculty. These events can involve students presenting research to their peers and faculty and/or industry; CREST faculty giving formal or informal presentations to industry and vice versa; invited distinguished speakers from academic or industry; and poster sessions for students to present work to industry, among many other variations. A customized workshop at the request of industry is often one of the benefits of industry involvement with the CREST, with fees for special topics determined on a project-by-project basis. Students and faculty may be involved in workshop development and presentation. These workshops are an excellent way for the student to obtain specialized training in specific industry topics of interest.

Some CRESTs present formal seminar series, which vary in format. Seminars and seminar series are sometimes videotaped and cataloged for industry use as part of the industry sponsorship package, or even for purchase by the public. The graduated Duke Center for Emerging Cardiovascular Technologies has held an ongoing videotaped seminar series since 1988, and maintains a large library of tapes accessible to industry and students. In every CREST, CREST graduate and undergraduate students present in these seminar series, along with industry, faculty, and business experts.

5-25. Lifelong Learning Programs

Lifelong learning, or continuing education, is an important outreach channel for CREST education programs-particularly significant in view of the interdisciplinary, industrially relevant research of CRESTs and its goal of a diverse, multicultural workforce. It is not enough for a CREST to train students and send them out into industry and academia. The Center's mission also includes educating the public in the developing frontiers of science, engineering, and technology; retraining engineering and industrial workers in new technologies and research areas; and designing programs to reach new audiences with new engineering and technological innovations. Continuing education is central to many CREST industrial and education programs. Many CRESTs develop short courses or workshops for industry, often co-taught by CREST faculty and industry.

Professional programs offer lifelong learning, particularly for career development and presenting CREST educational innovations to impact the young or established industrial engineer. These programs are attractive to

industry as means of keeping their work forces up to date and minimizing retraining time loss. With constantly changing technology and current trends towards industrial downsizing, the professional STEM practitioner is more and more pressured to be aware of current and relevant research trends. Industry needs the best quality and most efficient continuing education possible, and CRESTs are well positioned to deliver this service.

CREST education programs, in conjunction with industry, have developed certificate programs and distance learning models. Courses developed for university credit can be offered as distance learning classes.

The trend toward globalization and internationalization has affected CREST education programs, particularly in the industrial area. Many CRESTs bring in visiting foreign scientists and engineers and provide mechanisms and assistance for this process. In working out international exchanges of students, faculty, or industry representatives, special planning is needed to manage issues such as immigration, visas and work permits, international travel, and security. The education coordinator/director may need to work with industrial liaison and administrative director on various aspects of this planning and coordination.

5-26. Special Community Outreach

As the impacts of education programs grow, increasing numbers of CRESTs are designing programs for community outreach (broadly defined as the general public or specific targeted groups, such as dislocated or unemployed workers, at-risk high school students, or high school dropouts). The goals of these community-outreach efforts range from raising the scientific interest and understanding of the general public, to specific aims to retrain a group of unemployed workers or to provide career training and career potential for high school dropouts or at-risk students.

Community outreach for educating the general public is another important part of the CREST educational program. CRESTs are increasingly accepting a role in raising the general interest in science and in helping the public understand the value, role, and necessity of science in their lives. The CREST's role is part public awareness, part public education, and part recruitment of the next generation of scientists by raising awareness among both young people and their parents.

5-27. Educational Collaborations and Partnerships

NSF expects CRESTs to disseminate their educational innovations nationally and internationally, to spread their successes as widely as possible.

It is by these means that a Center can contribute to the reform of science and math education at all levels and help to bring more students into the pipeline for STEM. By working directly with schools, other CRESTs, academic institutions, and companies, in collaborative partnerships, CRESTs can propagate their successes through first-hand human contact-the most effective channel for transferring educational know-how or technology. Sustained collaboration is the key to success in this part of the CREST's mission. These arrangements allow CRESTs to share their best practices and thus enrich the learning experiences of students and the professional development of faculty and staff at all levels of education.

For the Centers, too, these collaborations have important benefits,. They give them, and the CREST Program, a reputation for innovative excellence. They allow the Centers to leverage resources and avoid "reinventing the wheel." They can help assure self-sufficiency after NSF funding ends.

This section reviews some of the most creative and successful partnerships.

Local Collaboration—CRESTs, if they wish to have meaningful and lasting impacts, must first of all take advantage of the programs and resources that can be found closest to home-in their own local schools, communities, and universities. These activities have several advantages:

- Generally they are cheaper and easier than working with partners who are farther afield.
- Colleagues in the CREST and in the university at large can help identify sources of funds and expertise.
- Local partners are potential sources of support for the CREST education programs. (Such support can be increasingly important as the Center approaches the end of its NSF funding cycle).

Collaboration Within the University—One vital secret of success for CREST education programs is to work closely with existing programs.

Collaboration with Community Groups, Local K-12 Schools, and Community Colleges—CRESTs can play vital and satisfying parts in their local communities in reforming science and math education (and education more broadly), improving the diversity of the population drawn into science and

engineering research, and enriching the scientific literacy of the general public.

CRESTs are in a pivotal position to do all of these things. Their expertise and their missions give them entrée to both industry (which is impatient for reform) and the teachers and administrators who must carry it out. They are able to draw on funds-from NSF, nonprofit charitable foundations, and industry-that may seem small but can have great impact if they are used strategically to leverage other resources.

Links with community colleges are another very promising channel for partnership with the community.

Collaboration on a National Scale—CRESTs by their nature have both a national and international scope, like the industries they work with. Their member companies must survey the whole world in recruiting and training the best personnel and in tracking markets and technologies.

Education programs at CRESTs must reflect that scale of vision in identifying the best educational practices. Partnerships with other CRESTs would seem highly promising, since the partners are sure to have parallel educational missions, and parallel problems. But institutions other than CRESTs are also fertile ground.

Working with industry to develop education programs is one of the most challenging tasks of the education coordinator/director. It requires detailed consultation and coordination with the Center's industrial liaison and key representatives of the industry partners and the CREST faculty, to find out what companies want and need. This coordination in turn requires awareness of technical and market trends in the relevant industries.

Education programs at CRESTs offer rich opportunities for interactions of faculty and students with industrial researchers, which may include mentoring, internships, co-advising on theses and doctoral programs, recruitment, employment, visiting scientist program, seminars, workshops, and presentations. (The details of this relationship are reviewed throughout this chapter.)

International Initiatives—Research and technology development are increasingly international enterprises. Education programs, if they are to give students the tools for productive and fulfilling careers, must reflect this trend. NSF, for example, has encouraged CRESTs to increase international

experiences in REU programs. A growing number of CRESTs have launched international internship programs, augmenting financing of students from international institutes.

5-28. Delivery Systems for Education Programs

Several factors have combined in recent years to increase the use of educational technology in engineering education. First is the increased availability and lower costs of the technologies themselves, from videotape to personal computers to television broadcasting via satellite. Larger class sizes and a growing demand for specialized courses for off-site students are also factors. Accompanying the growing demand is a scarcity of faculty to teach these courses (particularly undergraduate courses.)

For CRESTs, the existence of nearly identical courses at affiliated universities and the need to provide instruction to industrial affiliates and CREST students on multiple campuses provide incentives to reach remote locations. As a result, the CRESTs have pioneered the development and use of innovative educational technologies.

Remote Instructional Delivery via Television—Live television broadcasting of courses can be a daunting challenge. The technical systems are complex; it is difficult to establish natural communication and feedback from a remote site; the professor must perform on-camera; and start-up and operating costs are relatively high. Some CRESTs have found it hard to get students involved in distance learning courses. Experienced faculty and staff members stress the need to deal with technical difficulties early, because once the TV link gets a bad reputation, it is hard to overcome. Many CRESTs offer distance learning courses through their institutions' central "distance learning" or "outreach" program offices, to help minimize such problems.

Computer-Based Instruction—Students of all ages are comfortable using computer-based instructional software. These tools can range from sophisticated interactive simulations to simple tutorial text files that can be used inside or outside the classroom. Several CRESTs are also producing CD ROMs and/or providing web access to computer-based educational modules, workshop presentations, conference presentations, educational games, and other materials.

Use of the Internet for Instruction and Dissemination—The Internet is rapidly becoming one of the most popular delivery systems for instruction and

dissemination of educational programs. It has several advantages. It provides universal access to highly interactive educational materials for students, whether they are sitting in the same classroom as the instructor or halfway across the world. Access is virtually instantaneous and can be restricted to authorized personnel by implementing a number of effective security systems. Probably the most attractive feature of internet-based educational systems is that materials can be easily and quickly updated or upgraded. This fact is extremely important in science and engineering, where rapid change is the norm. While other delivery systems, such as live broadcasts, videotapes and books, represent the state of knowledge at the time those materials were developed, a well-maintained Web site reflects the current state of knowledge in a particular area. Many CRESTs are developing web-based educational materials, and one is developing authoring tools and management tools to assist with module development, course management, and delivery.

Conventional Publication Media—Most CRESTs distribute research reports and articles as part of their industrial programs, and many distribute final theses. Industrial workshops and annual industry meetings are used as forums for demonstrating new research and technological breakthroughs and software developments. Quarterly or biennial newsletters are the most common mechanism for publicizing CREST accomplishments. They feature both achievements in research and technology and educational innovations and programs.

5-29. Summary: Strategies and Lessons Learned

As the CRESTs have evolved, their education program developers and staff have devised a number of strategies and learned lessons that have benefited the Centers' education programs. Many of these are summarized below.

Education Program Planning and Direction—

- Funding for education should be consistent with its high priority among NSF CREST program goals. The support of the Center director is crucial.
- In planning an education program, the Center must align its vision and goals with the Center's strategic plan and objectives.
- The choice of an education coordinator/director will determine the success of the education program. The position should be viewed as a

full-time professional one, with appropriate flexibility, autonomy, and status.

- An education advisory committee should be established to give Center faculty a mechanism to provide input into Center education programs and to provide support for them.
- The initial budget should include sufficient funds to cover administrative costs, graduate student support, undergraduate research, travel for recruiting, and editorial and production help for dissemination efforts.
- Adequate baseline funding must be provided to the education program. A collection of supplemental grants alone does not make a coherent program, as not all funding opportunities will fit in the education strategic plan and only those that do fit should be pursued.
- It is prudent to develop an education program in phases that are implemented over several years, beginning with programs for graduate and undergraduate students in the Center's home institution(s).
- Strategic planning for education must consider the impact of the 11-year CREST life cycle. As a Center "graduates" from NSF support, the education program's survival depends on institutional support (including cash), motivated faculty, commitment to the goals of the education program, and a strong, evolving research program. The continuation of a graduated Center in some CREST-like form is essential to maintaining support for the associated education programs.
- As the Center matures, the education budget should include increasing contributions from sources such as industry members, NSF supplemental funding, and private foundations. Opportunities should be pursued to leverage the NSF funds using non-federal CREST funds for matching.
- A strong relationship with the personnel of the NSF CREST Program leadership, and especially with the Center's Program Director, will greatly enhance a Center's education program.

Education Programs—

- The CREST program offers innovative educational benefits for students: exposure to a cross-disciplinary systems view, teamwork, direct involvement of industry as faculty and mentors, communications training, mentoring opportunities, and exposure to the latest developments.

- Graduate students are expected to learn how industry operates and understand industrial perspectives, so that they are prepared to contribute immediately on the job after graduation.
- CREST faculty and staff should cooperate with the department and college in recruiting graduate students as broadly as possible (such as at professional meetings, by word of mouth with colleagues, and via the Internet).
- Financial support for graduate students can be obtained from a wide variety of sources, including grants from NSF, industry, private foundations, and federal and state agencies.
- Outreach to graduate students in outside institutions can best be obtained by forming long-lived collaborations with the faculty and staff of those institutions. Both domestic and international collaborations are vital.
- The emphasis on undergraduate participation in research is a special feature of the CREST Program. For undergraduates, the CRESTs have established their own variant of the competitive NSF Research Experiences for Undergraduates (REU) program, with an emphasis on recruiting from a diverse population.
- An important feature of most CRESTs is the student leadership council, which gives students a collective voice in the Center's affairs and fosters leadership skills.
- Educational partnerships with community colleges and technical institutes have great potential, but are only beginning to be implemented by a few CRESTs.
- CRESTs' outreach to K-12 teachers and students (through means such as summer camps, workshops, competitions, lab tours, and school visits) is an important contribution to reforming science and math education at the precollege level and expanding the student pipeline for engineers. Each CREST should determine what precollege offerings make sense in the context of its strategic plan, resources, and community relationships.

Curriculum Development—

- Establishing a new CREST curriculum is a challenging and complex task, involving coordinating many faculty members in an interdisciplinary research area.
- New degree programs, in particular, require substantial long-term institutional resources and commitment from the CREST and the parent university.

- Nonfaculty CREST staff who wish to develop undergraduate or graduate courses should find interested faculty to champion them and arrange with the professor's department for a reduction in teaching load to allow the needed time. Beta-test course materials. If your CREST is a multi-university Center, work on mechanisms to offer credit for students to take the course at other CREST universities.
- Find a vehicle, such as CD, web, or book, for wider distribution of course materials.
- A new minor degree program must be especially well coordinated with the existing academic standards and structures of the university. The key to successful development is to build on student interest and enthusiasm.
- Involve students (undergraduate or graduate) in evaluating plans and implementing the new program.
- Professional certificate programs, if properly planned and delivered, can help meet the demand for continuing education in the CREST's associated industry and improve the reputation of the Center. CRESTs that offer such programs, however, must allow for enrollments that fluctuate with swings in the economy.

Educational Outreach to Industry and Communities—

- CRESTs are expected to carry out educational outreach to industry and the wider community. The link between industry and education is one of the determining factors in the success of an CREST, and the strength of this link is a crucial element in the longevity of the Center.
- Educational links to industry involve mutual learning, in which knowledge flows both ways.
- The CREST's education coordinator/director should have a close relationship with its industrial liaison officer, because the two activities overlap strongly and affect each other's results.
- Establish industrial contacts/partners for the education program as early as possible, to help ensure industrially relevant education and industrial support in the later years of the CREST.
- Develop an interactive program with industry that brings industrial involvement at many levels.
- Industrial internships are one of the most valuable mechanisms for industry-CREST educational interaction. They provide vital technology transfer and educational experience for both undergraduate and graduate students, while giving the industry partners a thorough look at students as potential employees.

- Maximize student interaction with industry through poster sessions and presentations at industry meetings and workshops.
- Short courses provide not only continuing education opportunities for industrial personnel but also technology transfer both to and from the Center.
- Seminars and workshops are among the quickest, most efficient, and most economical ways to promote industry-CREST interaction involving students and faculty. They can be recorded on videotape or CD for future access.
- The Center's educational mission includes educating the public on developments in science, engineering, and technology; retraining engineering and industrial workers in new technologies and research areas; and designing programs to reach new audiences with new engineering and technological innovations.
- CRESTs make special efforts to reach certain groups (including underrepresented minority groups, unemployed or dislocated workers, and at-risk youth). In this role, the CREST seeks to improve public awareness of technology, improve the skills and knowledge of potential science and engineering students, increase the diversity of the engineering student pool, and recruit those students to the CREST itself and/or its associated institution(s).

Educational Collaborations and Partnerships—

- Sustained collaboration is the key to success in this part of the CREST's mission. By working directly with schools, other CRESTs, academic institutions, and companies, in collaborative partnerships, CRESTs can propagate their successes through first-hand human contact-the most effective channel for transferring educational know-how or technology.
- One secret of success for CREST education programs is to work closely with existing programs (such as in the college of engineering).
- Collaboration with local schools, communities, and universities should have a high priority, since it is generally cheaper and easier than working with partners who are farther afield. It also builds relationships with local partners that are potential sources of support for the CREST education programs.
- CRESTs are in pivotal positions to work with local communities to reform science and math education (and education more broadly); improve the diversity of the population drawn into science and engineering research; and enrich the general scientific literacy. Their expertise and their missions give them entrée to both industry (which

is impatient for reform) and the teachers and administrators who must carry it out.

- The opportunity to act locally should not blind CRESTs to their national and international opportunities, which reflect the technology and market scopes of the industries they serve.

Delivery Systems for Education Programs—

- CRESTs have pioneered the development and use of many innovative educational technologies. Their impetus has included the need to deliver nearly identical information to scattered locations (various affiliated universities and industry sites) on diverse schedules; larger class sizes; and a growing scarcity of faculty.
- Live television broadcasting of courses faces severe challenges, including the complexity of technical systems, the difficulty of establishing two-way communication; and the need to "perform" on camera. It is sometimes difficult to get students involved in such courses, or to stay involved if technical difficulties give the link a bad reputation.
- Some CRESTs use videotape recording to capture some courses, seminars, and/or industry presentations for later viewing by students (including industrial personnel) at remote locations.
- Computer-based instruction-distributed through CD ROMs and/or web access-offers convenient access to educational modules, workshop presentations, conference presentations, educational games, and other materials.
- For Web-based learning systems, standards are being developed by government and industry, but these standards remain immature.
- New CREST-initiated web-based authoring and delivery systems are under development that should influence standards and ultimately improve the development and delivery of educational materials on the Web.

5-30. Chapter References

NSF Engineering Research Centers Best Practices Manual. Online at: http://www.erc-assoc.org/manual/bp_index.htm, accessed 8/04.

CREST Best Practices Manual
Chapter 6: Technology Transfer

Contents

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EDITOR'S NOTE—this chapter is taken nearly verbatim from the Engineering Research Centers' Best Practices Web site (online at http://www.erc-assoc.org/manual/bp_index.htm), which may be consulted to compare and contrast with the CREST practices detailed below.

6-01. Introduction

An important part of the CREST program is to form partnerships between academia and industry in systems-oriented research areas that are critical to the nation's economic strength. Each CREST collaborates with industry from the early stages of its vision creation and strategic planning, and collaboration extends to technology development and application. By thus expanding and accelerating technology transfer and eventual commercial use, this approach bridges the traditional technology transfer gap between the single university investigator and industrial adopters of academic research results.

The CRESTs are distinctive among NSF research Centers in this embracing of industry throughout the entire cycle of technology creation, development, and implementation. Each CREST team envisions and plans technology development with its industrial partners from the outset. Each Center's strategic plan, developed with industrial members, helps identify areas for joint projects and experimental testbeds for validating research results in practical applications. NSF holds CRESTs responsible for tracking their research results through commercial implementation.

Special emphasis is often placed on attracting small and medium-sized companies to CRESTs because of their more rapid acceptance of new technologies and rapid growth potential. CRESTs are not discouraged from involving foreign-owned companies as long as reciprocity of information, expertise, and people is emphasized.

While all CRESTs are expected to plan, create, validate and transfer new technologies, some of these activities inevitably receive greater emphasis at different stages in a Center's life cycle. New "start-up" Centers (years 1-2) necessarily focus on strategic planning with industrial members, attracting new members to their efforts, and developing forums for interaction. Mid-term Centers (years 3-4) must focus on demonstrating successful industrial collaboration and technology transfer results, promising more to come beyond the fifth-year. Mature Centers (years 5 and 6-10, as applicable) are putting new technologies into play while attracting new companies and

finding new ways of teaming with industry without NSF support, including generating industrial endowments. Successful Centers engage in long-term planning jointly with industrial members beginning in the early stages.

Experience shows that the enthusiasm and appeal of a start-up Center is very effective in attracting industry involvement; but as Centers mature, industrial collaboration requires more work, as sponsors become more demanding. On the other hand, age confers the advantages of experience and credibility. In the early stages, Centers need to set modest membership fees, focus research on knowledge and technology development, and use industry as a partner in identifying problems. In later stages, Centers may shift their base to large contracts with specific companies; research then should include a focus on applications and field-scale development based on the knowledge and technology developed, while maintaining a base of new and exploratory work.

Another way of viewing the Center's life cycle is to consider that, in the first few years, NSF acts as a venture capitalist, funding a build-up of infrastructure and providing substantial leverage to industrial support. By year 5, the Center has "gone public," establishing a certain amount of credibility with regard to its benefits to industry, and begins to face a new set of challenges. With the infrastructure in place, the Center matures, and the issue of delivery becomes preeminent.

Industrial collaboration with CRESTs extends beyond the development and transfer of technology. Industrial members become involved not only in strategic planning and collaborative research, but also in many educational activities. Industrial members give practical experience to CREST faculty and students by hosting faculty sabbaticals, student internships, and on-site CREST seminars. Members also participate at the Center in hands-on courses, seminars, and co-advising graduate students.

Industrial involvement in the early stages of technology planning and development provides substantial payoffs when CREST students graduate. Member companies employ a large fraction of CREST graduates. Many of the hiring companies have noted that CREST graduates, by virtue of their systems-oriented training, are more skilled at technological innovation and product/process development than their non-CREST counterparts. They also are capable of integrating knowledge across disciplines, working in teams, understanding industrial needs, and addressing problems from a science, technology, engineering and mathematics (STEM) perspective.

The CRESTs' relationships with companies are experiments. Each one is unique, depending on the nature of the research undertaking, the scope and type of the industries involved, and the strategic direction of the Center. Within this diversity there are common issues, which each Center must resolve to create a functioning partnership with industry. The objective of a CREST should be to establish a very broad industrial constituency. Emphasis on the dollar amounts of support should be balanced by a focus on the intellectual and economic potential of a collaborative effort.

Ultimately, the CRESTs are testbeds for broader cultural change in university-industry collaborative research. They are pioneering new ways of bringing research results to market, breaking down many traditional barriers that have hindered cooperation between universities and industry. Every lesson they learn makes it easier for those who follow to work together productively, as the working partnership of university administrations and faculties with corporate researchers develops. This is perhaps even more true of the Centers that have graduated from NSF support, since those Centers operate without federal subsidies and therefore must justify their benefits to both their host universities and their industrial members.

This chapter discusses some of the most effective practices that existing CRESTs have learned to use in conducting industrial affiliates programs. It addresses issues such as establishing a partnership with industry, building an industrial constituency, the benefits and difficulties of industrial interaction, and the role that the NSF plays in this involvement. Case studies are used to illustrate some effective approaches. At the end of the chapter is a summary of the main lessons that have been learned; most of the sections also have a listing of specific lessons learned.

6-02. Establishing An Industrial Affiliates Program

Start-up Systems Development—A critical start-up activity in any Center is to establish the vision and infrastructure that are required for an effective industrial collaboration and technology transfer program, including systems for tracking interactions with industry. The Director and senior leadership of the Center typically form the vision and strategic plan for industrial interaction during the Center's proposal development process. The infrastructure required to effect this vision and strategic plan must be developed with post-NSF survival in mind.

In the months after the formation of a new Center, it is important to work with the university and its technology transfer office to establish internal support and work out a CREST membership agreement or memorandum of understanding for the program. In multi-institutional CRESTs, where university/industry research Centers may already exist, it is essential to examine and compare the existing membership structures, fees, and terms and conditions and involve all key personnel at the universities from the start in drafting the new CREST agreement. Support for the CREST is generally high immediately after the award of the cooperative agreement, and the climate for negotiating long-term university support is good. Some Centers have negotiated return of overhead from grants received by faculty doing Center-related research. In most universities the return of intellectual property revenue is divided according to a certain formula that includes the inventor, the university, the originating unit (the CREST), and other parties.

An important component of the strategic plan for industrial interaction is a clearly defined marketing strategy for recruiting industrial sponsors. A well-developed marketing strategy typically includes an analysis of the industry sectors affected by the Center's research and of the value drivers that industrial sponsors will find attractive in a research and technology transfer relationship. The marketing plan includes financial and technology transfer goals, specific actions and timelines needed to reach those goals, and a budget for the Industrial Affiliates Program. This plan includes strategies not only for recruiting new members, but also for retaining existing ones, through customer service activities such as communications on Center research activities and results, faculty interactions with sponsor companies, and regular visits to sponsors' sites.

Advertising and "cold calls" to potential sponsors usually are not successful. Centers should instead target specific companies based on their involvement in the particular industry, their interactions with other sponsors, and their degree of involvement in technology development. The use of current industrial partners to identify leads is particularly effective in identifying potential new members. As in many business endeavors, perseverance is rewarded in recruiting sponsors. Strong and continuous follow-up with several people in the organization, often involving visits to the Center and to the company, is usually required after the initial contact. For a new CREST without a track record, it is a good idea to market the Center's program and vision. This approach can be particularly effective with companies that have been involved with other CRESTs.

As in any customer-oriented enterprise, it is important to develop systems for tracking interactions with companies and assessing the effectiveness of the industrial collaboration and technology transfer; CRESTs and NSF regard this capability as vital to any Center's success. Most Centers find it useful to maintain a contact log, to augment memory and to provide reminders on follow-up action items. In planning such a system, it is important to consider who will use or access it, how it will be backed up, and what features are important. At minimum, a Center needs a complete company mailing list and a procedure for keeping it current. Security issues may arise if companies require that the list be used for Center activities only (a reasonable request). In designing the system, one might also plan for the impromptu reports that will be needed, such as lists of currently active member companies or current fiscal information. NSF's database and reporting requirements call for accurate data on company membership, support, and other forms of involvement, which must be validated by the university's office of sponsored research.

As explained in more detail below, each CREST has a staff member who is responsible for establishing and maintaining liaison between the Center and its industrial sponsors. Other commonalties, discussed in this section and elsewhere in this chapter, are the establishment of membership levels, contractual agreements, fees and benefits; intellectual property arrangements with the university; and reporting and communication mechanisms.

In a multi-institutional CREST, marketing, recruitment, and retention plans must reflect not only the vision of the Center, but also the cultures of the individual institutions. Universities with strong industry relations prior to hosting CRESTs need not invest as much time in recruiting new companies, but need instead to develop more comprehensive communication and retention strategies that reflect upon the Center as a whole. In other cases, such as when a multi-institutional CREST has more than one pre-existing industrial consortium, it is vital to develop from the start a clear mechanism for merging the consortia to ensure a seamless transition.

Other cultural differences that need to be addressed at the beginning of a Center include the degree to which the Center desires to enlarge its research and education programs, the balance of academic and industrial goals, and the long-term vision. In addition, all of the Center's principal investigators must support the Center's mission and strategy. Many of these issues can be

discussed and clarified in the development of a comprehensive marketing plan.

Membership Rights—During its first year, each CREST develops a standard membership agreement that governs members' participation and sets out the forms of cash and in-kind contributions that constitute membership. Organizations that can be considered as members include private firms and local and federal agencies. Organizations contributing research and educational participants in the Center, such as other universities, institutes, and hospitals, should not be counted as members. A CREST should be mindful not to develop unique contractual arrangements for each company in lieu of a membership-defined program of industrial collaboration. However, member companies may augment their support to the Center through directed project support or contractual arrangements. Firms that are not members but provide directed project support often are classified as "affiliates" and firms and others that provide equipment and other donations are classified as "contributing donors."

Intellectual property rights arrangements specified in the membership agreement are influenced by the type of industry, by the university's experience, and (it is to be hoped) by common sense. The type of membership structure also should influence IP decisions. If all the Center's research activity is precompetitive and supported in common, shared rights for all members are appropriate. If the Center has, in addition to generally supported research, special project support by a company, the arrangement should reflect that company's unique contribution and rights. In a typical Center, the university owns IP and licenses are available to members. Access to licenses is based upon membership category, varying from royalty-free license to all Center-developed IP to no access for any members. Other IP issues that may be included in the agreement or dealt with on a case-by-case basis include restrictions on licenses, who pays for and maintains patents, and royalty amounts.

Member Responsibilities-Boards and Committees—A Center's organizational chart reflects the formal role that industry plays in advising the Center. All Centers have industrial advisory boards or committees that serve functions such as the following:

- Provide advice on developing the strategic plan
- Review overall progress against strategic goals

- Suggest changes to the strategic plan, research, and education efforts
- Identify areas for cooperation with industry or, in some cases, other institutions
- Discuss the strategic plan and suggest modifications based on research results
- Review invention disclosures and suggest patent action
- Critique the progress and direction of each research project
- Provide resources the research program may need
- Appoint industry speakers for workshops and seminars
- Carry out an annual SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis of the CREST.

Because these activities are both technical and managerial, many Centers have corporate advisors who come from both those groups within companies and who form two different types or levels of Center advisory bodies (see case study). In most Centers, the technical advisors meet formally at least twice a year; upper-level management advisors usually meet annually. A company's membership category determines how many advisors it may have and at what levels. Advisory committees may be chaired or co-chaired by industrial members, usually vote on key issues, and often have minutes and action items distributed.

The two main customers of a CREST are its students and industrial partners. It is essential, therefore, to make sure that the CREST's initiatives match the voice of its customers. One way to ensure full endorsement is to engage them in the formulation and implementation of the CREST's initiatives.

At times, some CREST members may feel the need to explore research directions that do not map perfectly onto the CREST's core research goals. It is the CREST's responsibility to meet this need by collaborating with these companies under other mechanisms, such as sponsored contract research or fellowship research. CREST industry partners should be made aware of the various collaborative opportunities and should have a clear understanding of the difference in policies under the various options, especially if it involves a multi-institutional CREST.

Research and Education—Another CREST advantage that attracts industry is the opportunity for integrating research and education. It is thus essential for

CREST industrial liaisons to ensure that their industry partners are optimizing their investment by becoming fully engaged in the CREST's education and outreach activities. Other than professional short courses and workshops, CREST industrial outreach initiatives may include internship programs, fellowship programs, mentorship programs, and industrial residence programs. The case study below illustrates a prime example of a partnership that benefits both the CREST and its industry partner in research and education.

Lessons Learned: Establishing the Program—

- Developing a reliable computer-based tracking system for industrial interactions is essential.
- Developing a standard membership agreement that will stand the test of time is important.
- Building long-term industrial relationships should be the focus of substantial effort.
- Policies concerning the distribution of intellectual property rights among member companies, the CRESTs, and the university should be flexible and appropriate to the nature of the industry and the membership structure.
- Because of the diversity of the role, clearly established boundaries help an Industrial Liaison Officer thrive.
- Staff support for the Industrial Liaison Officer, if affordable, can greatly facilitate the success of the Center's industrial interactions.
- Support for faculty members should be restricted to those who interact with industry or are willing to begin doing so.
- Close interaction with industry is necessary to ensure effective two-way communication.
- Respect from faculty members is often hard to achieve in a nonfaculty role; the Industrial Liaison Officer should make special efforts-such as giving seminars-to increase understanding of his/her role.
- Flexibility-for example, in membership levels and fees-is essential in the start-up phase of an CREST.
- Effective planning is essential, but remember that one cannot plan for all possibilities, so it is necessary to remain flexible and open to opportunities.

- Key issues in establishing membership agreements include:
  - Complexity or simplicity of agreement vs. addressing critical issues downstream
  - Granting intellectual property rights (industry driven)
  - Identification of negotiable terms with university
  - Flexibility to negotiate vs. commonality
  - Subcontracts with partner universities (invention reporting and handling when combining CREST research sponsorship with previous or other sponsorship; division of returns)
  - Need to establish baseline agreements before implementing marketing programs
  - Recovering from earlier versions. (It is easier to expand than reduce benefits.)

6-03. Building An Industrial Constituency

The need to attract new members continues long beyond the start-up phase, as all Centers experience turnover in membership due to shifts in corporate strategies and fiscal constraints. Many Centers have formal criteria, often developed with the Industrial Advisory Board, for identifying those companies that may belong to the Center. These criteria deal with issues such as foreign firms and multinationals, whether consulting firms may belong, and whether company size or location limits membership. (It is noteworthy that, while some Centers have a geographically concentrated membership, no Center limits membership based on location, and many have all of their members at long distance.) This section addresses successful strategies for recruiting appropriate members.

Strategic Plan for Recruitment—The Industrial Liaison Officer manages this activity. Centers vary significantly in the formality of their strategic plan for recruiting member companies. A few Centers function only in response to inquiry, without active recruiting (not a wise approach). Most of the Centers focus on identified industry groups (sometimes with IAB input) and establish membership goals, do market research to further identify appropriate company prospects, and tailor recruitment strategies for each prospect. This approach is recommended.

Marketing the Center—Every Center uses its Director, staff, faculty members, and sometimes students in its marketing efforts, actively or responsively. At least one Center uses a part-time consultant to contact potential sponsors to identify and explore areas of mutual interest. It is the high quality of research (and graduates) that is always most valuable to companies. Carefully identifying the companies that might benefit from the research in

the Center-that is, finding the right partners-is important in successful marketing. Presenting information about the Center's respected faculty members must be accompanied by clearly defining the value of Center participation from the company's perspective. This is particularly difficult in industries with a poor track record for R&D funding. Marketing techniques include literature, newsletters, and brochures; visits to industry by directors and faculty; visits to the Center by industry representatives; booths and exhibits at trade association meetings; participation at technical society conferences; publication of technical papers; participation in industry research consortia; a Center website; informational videotapes; letters to potential industrial sponsors identified through contacts; and topical workshops.

Consider that it may also be in the members' best interests to join in the recruitment process. If so, it is important to arm member "recruiters" with information about the Center and its industry partner program. Additionally, the Center's recruitment of industry support may align with and add to university or school development program goals. If so, leveraging the assistance of institutional development officers may help in identifying prospective members.

Centers disagree on the value of various printed materials in marketing, but most believe that personal contact (at professional and trade meetings or other "natural" venues) and visits are very effective. Particularly valuable, it is thought, are visits to companies by teams composed of Center faculty, Director, and Industrial Liaison Officer. These visits not only introduce the Center to a broad audience of company personnel; but also help the CREST understand the company's products, business climate, and issues so that the value of CREST membership can be specifically defined. In arranging such a meeting, the Industrial Liaison Officer should gather in-depth information on the company, brief the Director and faculty, and set objectives for the meeting in advance.

The Internet may be an increasingly productive source of low-cost "passive" leads. One Center found that several industrial contacts had resulted from companies referring to the Center's website. Special sections of the site geared to industry can be valuable; some CRESTs have established password-accessible pages for members.

Industrial Consortia and Governmental Groups—Some Centers have worked with external industrial consortia and/or with state and local governments-

particularly those agencies involved in economic development. Besides meeting specific consortium or agency goals, such interactions need to pass the test of leveraging the Center's activities, augmenting the benefit to member companies, and contributing to student and faculty development. Several Centers collaborate with state agencies in programs with small companies-from directed research projects with undergraduate students to state-assisted start-up companies based on Center research.

Start-up and Small Companies—Identifying mutually beneficial relationships with start-up firms and small companies is challenging for most Centers. These companies' small R&D staffs and immediate product concerns often hinder them from participating actively in Center research projects and activities. When approached, their initial reaction often is that they may need immediate consulting assistance or they want to hire students, but could not benefit from full membership in a Center. Nevertheless, in high-risk research areas such firms may represent an important mode of technology transfer. Most Centers have developed special ways of working with small companies to make joining possible (such as reduced-rate memberships or short-term project teams of undergraduate students with faculty and industry researchers). Marketing the Center to such firms can emphasize benefits such as access to prospective product buyers from large companies at meetings; a window on the future directions of the technology; access to prospective employees; and any special programs developed. Teaming with small firms on proposals to other agencies also is an effective way to establish a partnership.

Most states have programs to support the development and commercialization of technology by small companies. They may provide business incubators, help in applying for Small Business Innovation Research (SBIR) grants, matching funds for federal grants, or even direct equity investments through venture or seed capital funds. A useful source of information is the State Science and Technology Institute, a nonprofit research and education organization that tracks such state programs and monitors the state-federal relationship in science and technology. It can be found on the Internet at <http://ssti.org>.

Foreign Firms—NSF recognizes that a CREST may have a global dimension, since many research and education challenges and opportunities require overseas collaboration to bring the best resources to bear on a problem. NSF policy permits foreign firms to be involved in an CREST if they agree to operate on a quid pro quo basis, exchanging personnel, sharing support,

risks, benefits, information, and their own facilities to the same degree as all other participating U.S. firms do.

Involving Industrial Members—Key to a Center's impact through relevant research and potential student hires is the depth of commitment and active participation of industrial researchers in Center programs. Exploration by Centers of the best ways to achieve a sense of "seamless community" with their partners attests to the creativity and flexibility of Center personnel. This section summarizes Centers' experiences in encouraging involvement by industrial members.

Industrial Input into Strategic Planning—Strategic planning for the Center's research, education, and industrial collaboration and technology transfer programs is a vital segment of the activities of all CRESTs. Most Centers rely heavily on their sponsors and industrial advisory groups for input into their strategic planning. There are several vehicles for doing this, some formal and others informal. Some advisory boards and technical advisory groups hold special strategic planning sessions; some consortia engage in road-mapping activities. Several Centers survey members to gather initial information for planning discussions, including recommendations for and evaluation of new projects. One-on-one interviews are also employed.

Mechanisms to Enhance Interactions—Of all the approaches used to expand and deepen industry involvement in Centers, nearly all Centers agree that the most effective are personnel exchanges and joint research activities, both of which foster one-on-one interaction. Successful collaboration must benefit both the collaborating individuals and the cooperating organizations sufficiently that obstacles (and there are many) will be overcome.

Most Centers attempt to broaden their interaction with member companies and provide a variety of ways in which companies can interact. Frequently used mechanisms that have been found to be effective include:

- Student internships at company sites
- Student mentoring by industry
- Industry participation on thesis committees
- Faculty sabbaticals
- Extended visits by industrial researchers

- Technical review meetings (review and topical)
- Industrial Advisory Board meetings
- Visits (of varying lengths) by industry to the Center and by the Center to industry
- Collaborative research projects
- Contract research projects
- Consortium meetings
- IP licensing
- Hosting Center tours for members and their clients/prospects
- Tours of member facilities by visiting colleagues
- Short courses

It is important to develop one or more champions within each company. Usually these will be firms' representatives to the IAB, but there may also be an additional strong supporter of the Center within the company's top research management or general management. These people go to bat for the Center when continued membership is an issue. They may be proactive in disseminating Center products and information within the company; and they look for joint research opportunities. An enthusiastic and forceful champion-preferably in a senior executive position at the company-makes the difference between a strong corporate member and a pro forma, uncommitted one. In one company, the Center's champion died and the Center subsequently lost the support of the company. If the industrial representative must step down, due to transfer, promotion, or other cause, it is crucial to enlist his or her help in identifying a suitable replacement champion.

Industry/University Collaborative Research Teams—CRESTs have found that close, personal liaison and one-to-one collaborations with industrial sponsors are very effective methods of technology transfer. Most Centers have established cooperative projects where Center personnel and industry partners have specific responsibilities and meet regularly to review progress and determine directions. In some cases industrial researchers provide leadership on project teams.

Faculty members join CRESTs because of their interests in industrial problems and in systems-oriented, interdisciplinary research. Centers

encourage this inclination by making funding available for research done cooperatively with industry. In some cases, specific projects or contract work are equally as effective in promoting industrial collaboration. Faculty members learn about industrial interests (and those of academic colleagues) through participation in Center reviews, visits by and to companies, and serving on thesis committees with industrialists. Some Centers provide released time and salary support for faculty; others do not.

Information Exchange with Companies—One problem identified by Centers is how to share information broadly within member companies when active participation often is limited to a few individuals within each company. This is a two-way problem, with faculty members needing to know more about the company's interests and industrial representatives needing a fuller understanding of how they might benefit from the Center. Most Centers try to distribute written materials as widely as possible within member companies. Publications distributed by most Centers include newsletters, technical reviews and annual reports, reprints of research articles, information on intellectual property, and summaries of meetings of advisory groups. Assessment of the effectiveness of these materials varies; each Center must determine what works in its own industrial environment. Many are using extensive Center Web sites and companies' internal electronic mail systems to share information. Others are trying electronic forums and video-conferencing as ways to broaden awareness.

As much as possible, communication should be individualized to the corporate culture of each particular company, to facilitate communication and increase awareness of the Center-within large companies particularly. Agendas for review meetings need to include significant time for industrial participants to interact with the material and its presenters. The traditional academic one-hour presentation-with an introduction, methods, results, summary, and conclusions-involves one-way communication that may be inappropriate for an industrial audience. The point is to meet the audience halfway by making the sessions interesting from their perspectives and leaving time for listening and interacting. No matter what format is used in research review meetings, it's important to plan and manage the presentations to ensure that they are aimed at the industrial audiences' interests and needs. The industrial audience wants to know the industrial relevance and application up front, while academic presentations typically start with a strong focus on the "science" and pay little attention to applications, except as an afterthought. It is important to keep cultural differences like this in mind whenever the CREST presents its results to

industry, to clearly demonstrate the value that industry sponsors are getting for their investment in the CREST.

Research review meetings include all researchers (faculty, students, and industry); in some Centers they are open to all interested companies and in others are for members only. A few Centers with closed meetings allow prospective members to attend one session as a marketing tool. Some Centers mix a public meeting/dinner on one day with a closed member meeting on the second day, thus giving prospective members the opportunity to interact with current members without being part of the exclusive group. Some of the Centers charge company representatives for attending meetings; others include the costs in membership fees. Some Centers use hotel meeting facilities, while others hold the meetings at university sites. In either case, proximity to CREST facilities allows tours and laboratory visits to be included, either formally or informally.

Agendas of research reviews vary from Center to Center. Typically such a review is held during a 1½- to 2½-day meeting, which may include: a plenary session overview of activities; consecutive or simultaneous technical sessions covering major research areas; roundtable discussions (sometimes including an outside perspective, e.g., clinicians for biotechnology); poster sessions (at several Centers combined with lunch or a buffet supper); and industry feedback sessions. Some Centers use the "raw" feedback from such whole-group sessions for guidance; others have representative technical advisory committees that meet in formal session to codify input. Experience suggests that these committee meetings are more effective with a clear agenda (ideally prepared with industry input), minutes, and action items, and seating around a table rather than classroom style.

Another typical formal Center meeting type is a topical workshop, often with topics recommended by industrial participants. These are often one-day sessions led by an academic or industrial organizer (or team). Presentations or panel discussions are arranged with sufficient time for discussion. Such meetings are an effective way to explore possible new research directions for a Center.

Centers' (usually annual) meetings with Industrial Advisory Board members vary considerably, but many are 3-6 hours long. Some are chaired by elected industry representatives who set the agenda; others are chaired (preferably with a light hand) by Center directors. It is important for the entire leadership team of the CREST (Director, Deputy Director, Thrust Leaders,

ILO, and Administrative Manager) to participate in this meeting. Industry participants should be made to clearly understand that this is their best opportunity to guide the CREST and therefore they should not be inhibited in their discussions for any reason. Distribution of the agenda and pre-meeting materials 1 to 2 months in advance facilitates the meeting. Including the last Board meeting minutes as part of the package is found to be extremely useful in conducting Board business. The CREST needs to include time during the meeting for their NSF CREST Program Director to brief industry on CRESTs and also for industry to conduct their Strengths-Weaknesses-Opportunities-Threats (SWOT) analysis of the Center.

Informal communication among faculty, students, and company researchers is usually face-to-face or via telephone, fax, or e-mail. E-mail is a very effective means of communication, as it is time-efficient and flexible as to reception and response. Most CREST faculty by now use e-mail routinely to communicate with other faculty, students, and their industrial researcher counterparts. Any senior faculty members who are not comfortable with the use of email should have a secretarial interface to email.

Finally, it's critical to note that one of the most important roles played by the Industrial Liaison Officer in communicating between the CREST and industrial sponsors is that of ombudsman or the "voice of the customer" in the CREST. The ILO typically has more direct experience in industry and everyday industry contacts than anyone else in the Center and he or she must be seen as an impartial advocate for the interests of the industrial sponsors-in essence, their internal advocate. Undertaking this role makes the ILO an invaluable resource to sponsors and serves the purpose of the CREST in fostering closer industrial collaborations.

Balancing Long- and Short-Term Research—Despite industry's perennial need for short-term (typically less than a year) problem-solving, several Centers reported few problems in matching long-term university research with industry's need for longer-term R&D. The continued participation of companies in Centers, based on corporate assessment of the value of the investment, provides Centers with a clear measure of the relevance of their longer time-horizon research efforts.

Centers that work with small companies or have contract work in their operation tend to have more short-term research in their portfolio. Examples of some of the balancing strategies used are involving undergraduate and/or postdoctoral research associates on short-term research projects, separation

of general Center research (long term) and contract research (short term), and obtaining additional direct funding of short-term projects.

Avoiding Conflicts of Interest—NSF policy limits the involvement of CREST faculty and staff members in positions of responsibility in member companies or, conversely, involvement of CREST member company personnel in decision-making roles in CRESTs.

Other Federally Funded Joint Ventures—Some Centers are participants in other federal programs (e.g., those of DARPA and NIST, such as the Advanced Technology Projects (ATP) program). On balance, most Centers see such participation as beneficial. Benefits include the industrial relevance of the work, strong commitment and involvement by industry, and willingness of other universities to work together collaboratively. However, not every Center finds these large programs beneficial.

Industrial Involvement in Education Programs—Industrialists are involved in Center education programs as both receivers and contributors. Several Centers have industrially focused short courses, workshops, and seminars and industrial degree programs that are offered on campus, at professional meetings, or at company sites. As contributors to Center education programs, industrialists lecture, teach entire courses (sometimes as team teachers with faculty), serve on thesis committees, work with students on project teams, act as mentors, and support students financially and with internships.

Measuring Program Effectiveness—Metrics used to assess the effectiveness of the industrial collaboration/technology transfer program vary among the different Centers. All Centers should keep track of the impacts of their work on companies-what was adopted, how it was used, the impact on the company, on the industry, and other indicators. Data quantifying the impact are especially powerful. In all cases, good "nuggets" describing the impact on industry are useful in explaining the Center's accomplishments and should be preserved to expand on the numerical listings. In addition to the Center's own use, this information is used by NSF for a variety of purposes.

Metrics used in existing Centers include: number of joint research projects with industry; number and names of students hired by member companies; number and titles of publications; number of patents/licenses; company funding figures; in-kind corporate contributions; number and names of companies attending Center meetings; number and names of industrial

collaborators on projects; number of faculty visits to companies; etc. Some Centers have found it useful to individualize the data by company to support Center industrial representatives in their justification of membership renewal, if requested.

In assessing its performance, each CREST is required to assess its strengths, weaknesses, opportunities and threats in a specified, structured manner. This SWOT analysis is a vital tool for the Center in its efforts toward continuous improvement. It is also among NSF's most important measures of the Centers' performance

Each CREST's industrial members perform a SWOT analysis in conjunction with the NSF site visit. Its purpose is to:

- Analyze the strengths and weaknesses of the CREST's vision, strategic plan, research, education, industrial collaboration, leadership and team, and management system.
- Identify any opportunities missed by the CREST.
- Determine if any weaknesses are serious threats to the CREST's ability to fulfill its vision.

They summarize the results of the analysis in bulleted slide presentations, for the use of the NSF annual review team and the CREST.
This exercise provides an integrative forum for industry members to focus on Center goals; builds more cohesive industry support; provides focused input to the CREST and to the NSF site visitors to help strengthen the CREST; and strengthens the investment partnership between NSF and industry by clarifying industry's priorities and concerns. The Center's NSF Program Director also participates in the meeting, briefing industry on the overall CREST Program and the SWOT analysis process.

A final note on technology utilization metrics: Licenses are an easily measured record of success. Perhaps a more significant cumulative impact, however, is gained from the little ideas and bits of information that spark an inspiration for someone, and when they take it back to their company it becomes an unmeasurable (but important) piece of some large system. One way to measure this is through testimony by working engineers within the company who have benefited from the interaction. Thus, perhaps another metric should be, "Has the Center established an effective forum for intellectual exchange within its technology focus area?"

Benefits to the Center of Industrial Involvement—In addition to the funding, strategic guidance, and personnel-exchange benefits discussed earlier in this section, Centers report nearly unanimously that industry also brings an understanding of what research is relevant. An understanding of the technical direction and needs of the industry is an essential element of systems-oriented, interdisciplinary research and helps provide students with an engineering systems perspective. CRESTs develop an awareness of which research is relevant through a variety of means, including Industrial Advisory Board meetings, people exchanges, visits to and by industry, one-on-one research collaborations, technical conferences and reviews, and ongoing technical interactions.

Benefits of industrial participation also include student mentoring through formal and informal research collaborations, student internships, and membership on student education committees. In addition, industry provides input on curricula, so that the education offered reflects industry needs; quality student employment opportunities, both full-time and part-time; research equipment, devices, and materials; help with equipment operating problems; access to industrial facilities for specialized testing; management experience and advice; assistance in obtaining funding from federal programs; and support in site visits with the NSF. Among the benefits are faster commercialization and the ability to do research in areas in which member companies do not have technical strengths.

Interaction with the leading companies in the industry increases the Center's credibility and prominence in the field, and can be very instrumental in attracting other companies to become members. This advantage is even stronger when existing members are willing to network actively with the Center and prospective industry collaborators.

Lessons Learned: Building the Constituency—

- Company recruitment strategies should be tailored to each prospect; prospective members can be "seduced" into partnership with the Center only when an appropriate confluence of interests exists.
- Bad research cannot be sold with public relations. Even world-class research with aggressive technical goals must be relevant to industrial needs or it will not attract the attention of industry.
- Recruiting nontraditional partners (government laboratories, state agencies, small start-up firms, and consortia) requires that the Center understand clearly how all parties can benefit from the collaboration and clearly communicate those benefits.

- You cannot have too many contacts or contact them too often; personal contacts and visits are very effective.
- Industry's presence has changed education-universities and industry now share a responsibility to create effective engineering leaders for the future.
- Industry's short-term needs must be addressed without disrupting the educational process.
- Industrial researchers enjoy interacting with students.
- It is important to have champions for the Center's program in each company. They do the internal persuasion and make the connections that keep the Center well anchored with its members.
- Academic and industrial cultures are very different, especially in time scales, attitudes toward deliverables, and perceptions of problems. This is true even in the oldest CRESTs, after 11 years of partnership.
- Mechanisms that foster one-on-one interaction (such as personnel exchanges and joint research) are the most effective way to enhance industrial interactions.
- Many faculty members enjoy, and most benefit from, the synergy of collaborative research with industry.
- Networking of CREST faculty with industry professionals via professional society activities, consulting, invited seminars, and other means is valuable.
- To gain the confidence of the industry, Centers must be able to prove concepts and provide solutions, rather than simply produce technical papers.
- Strong industry critiques of the Centers' research and education programs-and even their management-are useful; industry may even have formal channels for input into Centers' strategic planning and the SWOT analysis required by NSF.
- Routine mailings need to be automated and delegated for maximum cost-effectiveness and minimum impact on management workloads.
- As a Center matures, it undergoes a transition from informal to more formal interactions with industry; communications and meetings need to reflect that shift when it occurs.
- Metrics for assessing the effectiveness of the industrial collaboration and technology transfer program are vital and have many uses.

6-04. Intellectual Property and Commercialization

The major objectives of the CREST program include both developing and commercializing technologies to bolster the competitiveness of U.S. industry. To successfully bridge the gap between technology development and commercialization, CRESTs must take a holistic, integrated approach to technology (creation, experimentation, development, and implementation) that is unique among NSF-funded organizations. The involvement of industry representatives in goal setting, project review, technology evaluation, and technology implementation is vital to the success of this effort. In addition, if they are to be successful at commercialization, they must have ways to ensure the equitable treatment and ownership of intellectual property (IP) resulting from research by individual researchers, the CREST, the university, and industry sponsors.

Technology commercialization at CRESTs is a relatively new yet rapidly expanding art. The process is significantly more complex than it is where technology is developed and commercialized wholly within a single company or at a small business spin-off based on a university invention. The challenge lies in melding a commercially promising research agenda with the often disparate goals of individual industrial sponsors, guiding the resulting work to a point at which industry can use the product, and supporting the commercialization effort through continued close contact between CREST researchers and industry representatives. Both university investigators and industry scientists must understand that their roles will change from advisor to project director as a commercialization effort moves forward.

These challenges are significant, but CRESTs are well positioned to take advantage of the considerable experience of industry in generating value from new ideas. The CREST model has a built-in mechanism for maintaining industrial relevance, in the form of periodic project reviews and direction by industry representatives. Because most CRESTs are relatively new to technology commercialization, there are few examples so far of directly commercializable technologies that have emerged from their pipelines (although there are some significant ones) . More common is the transfer of ideas, which industry can refine and cultivate into saleable products. Whether such an idea is protected by patent or license depends on the extent to which the CREST or the industry sponsor developed the idea.

Because the potential for commercial success of ideas is difficult to forecast or control, it is important that CRESTs and industry forge a more fluid relationship with university administration concerning ownership rights to

intellectual property (IP). For industry, one of the main attractions of belonging to an CREST is the potential access to breaking technology that could bring competitive advantage. Indeed, this is the central purpose of the CREST. The role of the university patent office in maintaining strict control of ownership to this technology must be redefined to reflect the considerable financial and intellectual contributions that industry makes to the knowledge acquisition process.

Product Development and Commercialization—In fundamental research, a full understanding of the impacts and ramifications of the work is impossible at the outset. Industry, on the other hand, requires some projected future payoff to justify research funding. Bridging this dichotomy is at the core of the CREST mission. Of course, not all CREST research will result directly in a commercially viable discovery or technology; however, the likelihood of this result is increased by the periodic involvement of industry at critical points in the research planning and review process. This review process is akin to the product development model, which industry has used for many years. Applying this model to university-based research necessarily involves scaling back such things as market reviews and surveys as hurdles that a new idea must clear. What is useful about the model is the scheduled interaction among various stakeholder groups at critical points in the development (research) process.

Developing and Maintaining an Industry-Relevant Research Agenda—Developing the research agenda is a fundamental aspect of CREST management and oversight. However, the perspective of industry has traditionally been absent from this process in university research. It is essential that the CREST's research management team recognize the importance of industrial input, consider the opinions of industry representatives in their decisions, and encourage the research faculty and staff to do likewise.

Most CRESTs have established mechanisms for including industrial input in formulating new research and overseeing ongoing work. Most often, this opportunity occurs during an annual or semi-annual meeting of the entire industrial members group or some subgroup thereof. Depending on the diversity of interests among this group, research focus meetings can be held during plenary sessions of the meeting or in industry-specific breakout sessions with only those representatives interested in a particular topic in attendance. For projects sponsored by a single member or a consortium of members, only contributors to the project under consideration need attend.

The diversity of interests among members can make a group meeting of them and CREST researchers a challenge in setting agendas. Keeping these meetings focused on the goal of developing a consensus in the research direction is vital. Time should be set aside for constructive criticism of past work and decisions, if appropriate; but it is the role of the CREST research management team to keep the meetings on track and focused on setting realistic goals that are likely to produce tangible benefits to industry.

The Changing Roles of Academic and Industry Researchers in Commercialization—As the technology developed in a research project moves from the laboratory to the field, the roles of the project director at the CREST and the industrial sponsor will likely reverse. The CREST researcher at this point moves from directing the project into the advisory role, which had been occupied by the industry representative, and vice versa. In some cases responsibility for scaling up the technology may move to someone in industry who had not been connected to its laboratory development. In either case, the CREST researcher should seek to remain available and involved. In cases in which the CREST researcher has a financial interest in the commercial success of the technology (such as partial ownership of the IP), the incentive for involvement is obvious. The importance of input from the researcher in maximizing the chances of success of the technology (regardless of IP ownership) should not be overlooked, however.

Balancing the Needs of Researchers and Industry—Throughout the commercialization process, it is important to balance the needs of industry and the university. Where a university's central missions are teaching and generating knowledge though research and publication, industry is concerned with maximizing financial value. The potential for conflict between the two must be acknowledged and dealt with in a balanced manner. Questions about the nature of confidential information, the length of time a discovery must remain confidential, and how results can eventually be published are usually specifically addressed in the research contract and confidentiality agreement. The terms of these documents are usually negotiated among the CREST, industry legal staff, and the university technology transfer office.

Using Commercialization Successes as a Marketing Tool—Successfully commercialized technologies are valuable tools in marketing the CREST to prospective members. To the extent that technological advances cross industry lines, a new process or idea may enhance the appeal of CREST membership to previously underrepresented industries. The ongoing process

of market analysis for new membership should constantly evaluate the appeal of new technologies to potential sponsors.

Intellectual Property Rights and Ownership—The treatment of IP generated through industrially funded university research is one of the most challenging and potentially time-consuming issues facing CREST staff. Traditionally, universities in the United States have tightly held ownership rights to intellectual property generated by university research. As company-sponsored research has increased dramatically at universities in recent years, the equity of this policy has been challenged, particularly at universities with institutionalized industry-funding programs such as CRESTs. While outright ownership of IP is usually reserved for companies that both give generously to the general research program at the CREST and sponsor individual projects, access to IP through licensing has much broader potential for CREST member companies. An added complexity for CRESTs is the formulation of policies to equitably distribute IP and/or licensing rights from research funded by consortia of companies. To avoid misunderstandings and legal problems, policies concerning IP must be explicit in the CREST charter and membership agreement and must be understood by sponsors. These policies are typically negotiated with university administration in an ongoing process, to meet new situations.

Agreement with University Administration—All Centers work with their university intellectual property officers to comply with university standards on such matters. A good working relationship with the university IP administrators is important in developing a successful partnership with companies. If a Center spans more than one university, clear agreement among the administrations of all the academic partners is essential. Procedures for notifying members of the existence of Center-developed IP should be clarified between the Center and the university's intellectual property officer. In all cases, IP agreements should accord with regular NSF guidelines, as set forth in NSF Grant Policy Manual 95-26.

A related issue is distribution of royalty income. Most Centers use their university's defined split (usually 50-50) between inventor and administrative units. Whether the Center negotiates to be part of that split is another important early-stage decision. If the Center is not included in the formula, the director can approach the university administration and/or technology transfer office and negotiate a portion of future royalty returns to be earmarked for the Center. Because there is no "money on the table" during these negotiations, it may be possible to secure a future revenue stream

before the Center even begins its research. Taking a long-term view toward self-sufficiency for the Center, it is a good idea to be in on that split.

Membership Levels and IP Rights—Some CRESTs have developed "tiered" approaches to industrial associate membership, wherein companies may opt to increase their access to IP or licensing rights on projects they fund in addition to their membership dues in exchange for higher annual dues. The advantages of this system are that the CREST obtains increased annual funding based on the expected future value of IP and/or licensing rights. The details of the tiered membership system must be formulated in concert with the university technology transfer office and existing or prospective members.

The membership system in multi-institutional CRESTs presents an added level of complexity. Here, membership rights often reflect the least common denominator. For example, one university may be able to offer companies better access to intellectual property than other universities in the Center can. But it is important for the Center to present a single criterion of industry benefits, reflecting the consensus of all the partner institutions. Variations can be addressed internally, so as not to confuse the member companies. It is therefore imperative that negotiations between the multiple institutions of the Center be started as early as possible, because the development of an agreement suitable for all institutions can be very time-consuming. Once the institutions have agreed upon the Center's IP policy, a memorandum of agreement (MOA) should be developed and signed by all member institutions for documentation and reference.

IP in Relation to Funding Source—Treatment of IP rights varies depending on the source of the funds that generated that research.

- Core CREST Research-
  As with most university intellectual property, IP generated from CREST core research is not normally subject to ownership by industry, although industrial members may enjoy preferential licensing rights to this technology over non-associate companies. Industrial associates may enjoy the right of first refusal on licensing or may receive a discount in royalty fees compared with non-associate companies for IP generated from CREST core research. It is important in working with core IP that all members be treated equally in the licensing process.

- Research Funded by a Single Company-
  IP resulting from research funded by a single company may be subject to partial (or full) ownership by the sponsoring company, depending on prior agreement between the CREST, the university administration,

and the company. Some CRESTs confer ownership of IP from sponsored research to the sponsoring industrial associate member based on a premium level of membership. In other cases, the magnitude of the sponsored project may entice the university to partially relinquish IP ownership. Another option here is for the university to retain IP ownership but grant a free (or reduced cost) license to the sponsor for use of the technology.

- Research Funded by a Consortium of Companies-
  IP ownership and licensing rights are further complicated by the involvement of several companies (a subset of members) in funding work as a consortium. An important distinction to note is that these consortia are funding a project in addition to paying normal membership dues to the CREST. In this case, it is crucial that all members of the consortium have equal access to the technology and equal rights for IP ownership or use through licensing. Contractually, it may be most expedient to execute separate though identical contracts with each company, acknowledging the involvement of other companies that in many cases will be their competitors. A model for equitable treatment of companies is presented in the following subsection.

Patenting—Due to the significant costs involved in applying for patent protection for IP, most universities have full-time staff and/or a committee that decides if an idea, design, or process is worthy of patent application. Committees of this kind may include university administration, legal staff, CREST research staff, and the CREST industrial liaison officer. At some CREST universities, patent application costs are paid through sponsorship dues. This approach guarantees that adequate funding will be available to pursue patents on worthy IP before the generation of any royalties or licensing fees. Obviously, such receipts should replenish this account when they become available.

In determining the merit of an idea, process, or potential product, the advice of the university technology transfer office should be sought early in the process. Disclosure of the IP at the earliest possible date is important in establishing and protecting the rights of the inventor and university.

Lessons Learned: Intellectual Property and Commercialization—

- A significant reason many companies become CREST industrial members is the potential for early access to valuable ideas and/or processes. CRESTs must recognize this value and provide equitable access to technology for members.

- The development of commercially valuable technologies is enhanced by close cooperation of CREST researchers and industry

representatives. Early and periodic involvement of industry in setting and refining the research agenda is important.

- CREST researchers should remain involved in commercialization efforts even after the technology has been handed over to industry.
- The needs of university faculty to publish and the needs of industry to maintain confidentiality are frequently at odds. The details of confidentiality periods and publication must be specified in the research or membership contract.
- There are many approaches to sharing IP ownership among inventors, the university, and companies (sponsors). It is important to work with all stakeholders to arrive at an equitable agreement that is well understood by all participants, and that includes the CREST as the originating unit.
- It is wise to negotiate special overhead rates on memberships and royalty revenue splits with the proper university administrators in the early weeks of the Center, while enthusiasm for the Center is high.
- In multi-university CRESTs, discussions leading to the development of an IP arrangement suitable for all partner institutions should begin as early as possible.
- Much of the knowledge developed at an CREST is not appropriate for intellectual property protection. However, with early access to this knowledge and the opportunity to influence the direction of fundamental research at the CREST, members have many opportunities to implement this knowledge into leveraging their R&D and commercial developments. Thus, without the obvious tracking of commercial development through licensing of intellectual property, CRESTs must struggle to document the flow of knowledge into the U.S. technical markets. Testimonials and other evidence for this knowledge-to-market flow are important for an CREST to track and understand in order to validate the success of the CREST model.

6-05. Benefits and Difficulties for Industry Interacting with CRESTs

Industrial Benefits of Membership—Industrial sponsors of CRESTs generally feel very positive about the contributions of the Center to their industries. Many companies see the Centers as critical components of their industries' research and educational development. The major benefits fall into five categories: (1) access to new ideas, know-how, or technologies; (2) technical assistance; (3) interactions with other firms participating in the CREST; (4) access to CREST equipment and facilities; and (5) access to CREST students and graduates as potential employees.

Industrial Liaison Officers describe the main benefits of Center membership for industrial sponsors in much the same way as industrial members:

- Early access to highly leveraged cutting-edge research results not achievable in individual companies
- Access to a steady supply of graduates skilled in the newest technological approaches and in interdisciplinary systems thinking and with strong industrial orientation (since 25 to 95 percent of Center graduates go to sponsoring companies)
- Recruitment of top students into the field
- Interaction with other companies at a personal and technical level that would otherwise not be possible
- Maintenance of research project continuity over extended periods of time
- Use of CREST-developed specialized equipment for characterizing and evaluating research concepts designed to address industrial problems.

Other important benefits identified are preferential access to specialized facilities and equipment, access to faculty members, training for industrial researchers, influence on research directions in the Center, and participation in workshops, seminars, and research review meetings.

Job Performance of CREST Graduates—CRESTs give students broader, non-technical capabilities that make them more effective as potential leaders in industry and elsewhere. Supervisors and corporate representatives value these capabilities, and graduates identify CRESTs' impact as strongest in these areas as well. The CREST culture of interdisciplinary teams, research relevant to industry, and direct involvement of industry produces these results in students, but each CREST still needs to improve its impact on students. Graduates judge their performance in these areas as just slightly better than that of their peers, yet see themselves as clearly superior in numerous technical areas. They recommend that CRESTs expand significantly the exposure of students to industry, especially through internships. Long-term involvement in teams with industrial researchers is also necessary to broaden the students' experiences and capabilities in the areas that make them most effective in industry.

Benefits of University Consortia—In some Centers, another benefit to industry has been the opportunity to leverage the research and educational capabilities of more than one university. Some CRESTs leverage their faculty

effectiveness and enhance their credibility with industry by collaborating with colleagues at other institutions, either formally as co-PIs or informally.

Management of IP issues is a widely discussed topic across all the CRESTs. In the past few years, some of the key challenges, especially for multi-university CRESTs and CRESTs with subcontract participants, stem from efforts to clarify and establish clear procedures and policies.

Adopting such policies with multi-university CRESTs may not always be easy; procedures must be derived from the policies of each university. It may not always be necessary, or even desirable, to blanket all of the CREST's IP in such fashion. The key issue is to determine what is best for the long-term success of the CREST. In most cases, intellectual property law dictates the disposal of joint IP, and agreements that clearly delineate control of licensing are rationally derived. The lesson to be learned is that it is worth the effort and it is necessary to derive these systems.

Benefits in the Form of Spin-off Companies—Many Centers report entrepreneurial activity resulting from Center research as a benefit to the industries they support. In some cases, an independent entrepreneur works with Center technology licenses as the basis for the new venture. Legal issues are handled by the university's intellectual property officers and must conform to agreements in place with the Center's member companies. These start-ups sometimes include current faculty participation, so a clear understanding of the university's policies on conflict of interest is critical. In many cases, former students and/or former faculty members participate in the start-up.

Successes and Difficulties—CRESTs are risk-taking organizations. Most assume that if they are not regularly failing at something, then they are not living close enough to the experimental edge. The trick is to learn from the failures and integrate the resulting knowledge into the next attempt. This "change agent" mentality is what both NSF and industry say they want from CRESTs; but long-term success through strategic failure is hard to measure and justify. It is a uniqueness of the CREST Program that needs continued nurturing and protection.

Continued maintenance of the company membership base and recruiting of new members is more difficult than it was in the early days of the CREST Program. This is a result of economic stresses in industry and a much stronger desire by industry to ensure that clear, defined benefits result from

the funds that are spent for external research. Resource limitation is a problem at universities as well, with faculty time being a prime example. In some Centers, no industrial recruiting is done by faculty because they are overloaded. In the absence of strong university rewards for successful recruiting of Center members, faculty members choose to spend their time in other pursuits. This disincentive still exists. Other issues perceived as barriers to getting and keeping companies active in Centers are:

- Increasing costs of research at universities
- The problems of generic vs. proprietary research
- Publication requirements of universities
- The mismatch between short-term research questions and longer-term graduate education
- Dealing with the imbalance among sponsors' views of desirable long-term research directions
- Ineffective communication with upper-level management in sponsoring companies
- Overuse of the academic paradigm of published results (technical reports, papers) for the industrial audience, which is more attuned to technology application (whether or not the result was actually used to design or build something).

Effective interaction with industrial sponsors is most often limited by the failure of either industry or the Center to provide the resources (time and appropriate personnel) for interaction. It is important for upper management in sponsoring companies to understand that the greatest benefit from membership is the most costly in personnel time. Centers need to provide incentives to faculty members to continue developing partnerships with companies. Some Centers report that the key is the reward of the intellectual challenges provided to the faculty member by the company partner; but for this to be effective, the matching of faculty interests and those of the company researcher must be quite close. A related barrier to effective interaction is travel restriction-the first response of a company to economic stress. Some Centers are now using more of their own resources to visit sponsoring companies. The extensive use of email and the growing use of web-based interactions is designed in part to reduce the negative impact of these travel funding constraints.

It is worth noting that one Center identified contract research as its chief success while another Center identified contract research as its chief failure. It is a cliché, but also true, that any challenge represents an opportunity. And opportunities are just that, possibilities to be actualized in a unique setting. Each Center works within its own industrial and university environment and must choose its path, not based on what works elsewhere, but on what may succeed for it.

In addition to these successes and difficulties in the relationship with companies, it is important to recognize that the universities are perhaps the greatest beneficiary of the NSF CREST program. Today's academic environment is being swept by change in both the quantity and quality of industrial interactions. The CREST provides a challenging yet well-honed paradigm for achieving these goals. Most U.S. universities, despite great success in recent years, are still learning how to work efficiently with industry, and an CREST can lead the way. An CREST stands to benefit greatly as its host university and affiliated institutions continue to regard the CREST system as a trailblazing effort. Some of the chief benefits to the university are:

- If it can successfully conduct one consortium, it can grow to adopt new ones.
- The skills and coordination required to manage a consortium become fundamentally integrated with the disparate departments involved in university administration-especially in coordinating R&D contracts, IP management, and commercial licensing.
- An R& D consortium, built over many years, is an "instant marketing" system comprising a set of well-informed partners (as opposed to a series of one-at-a time and one-to-one handoffs). The consortium partners will tend to "pull on the rope," rather than pushing on it, as most universities do today.
- A well-managed group of targeted R&D consortia can be used to steer the university in new directions and to capitalize on underutilized assets, especially for faculty needing and seeking new research directions.
- For both new faculty and highly successful senior researchers, the consortium model developed along the lines of the CREST system, can lead to greater scientific and technological accomplishment overall. The scientific enterprise in such a highly coordinated, multidisciplinary system is an enormous drawing card to the best scientists. It is venturesome, but accurate, to compare CREST efforts to larger-scale

endeavors such as the Manhattan Project or the NASA's Apollo Program. These goals could be met only through a large-scale, interdisciplinary approach, and the excitement of their scope attracted the very best scientific and engineering minds. The goals of revolutionary engineered systems have the same attractiveness-especially for the most successful investigators at any university. Great science and technology attracts the best minds in any setting, and the overall mission of the university is given a quantum leap in scope with these consortium efforts.

6-06. CREST Program Support for Industrial Liaison

The National Science Foundation is a catalytic partner in each CREST. It selects experimental situations to leverage federal resources with those from industry and other private sources in targeted technology development. This section summarizes the best practices of CRESTs in using the NSF relationship to fulfill the industrial liaison function.

Importance of NSF Imprimatur to CRESTs—NSF imprimatur lends credibility to a Center. In addition, the opportunity to leverage industrial funds with NSF funds is attractive to sponsors. The tie to NSF also lends support to the Center's pursuit of long-term or basic research. The CREST has an NSF-funded management and operations infrastructure that makes the difference between a mere collection of faculty and an interdisciplinary Center with an ambitious mission. In a Center that is in start-up mode, the NSF connection is especially critical.

NSF Support for Industrial Liaison—A CREST is expected to have an active, long-term partnership with industry and practitioners in planning, research, and education so as to achieve a more effective flow of knowledge into innovation and to help the CREST produce a new breed of engineers. Since the circumstances for each CREST vary greatly, the methods of achieving this expectation are very different. However, there are many similarities across the CRESTs, as well as lessons each can learn from the others. Consequently, NSF has created periodic forums in which CRESTs can draw on the knowledge and experiences of others. The annual and biennial meetings are intended to bring together key people involved in the industrial liaison function from new, existing, and graduated CRESTs to promote cross-fertilization, establish networks of contacts, share experiences and insights, and open channels of communication. The consultancy is a team of experienced ILOs who visit new CRESTs to provide personalized guidance

and insight into establishing more effective industry collaboration and technology transfer.

NSF Program Director Role in Industrial Liaison—To foster an appropriate CREST environment and provide a personal line of communication, NSF assigns each active CREST a Program Officer (PO). POs provide guidance to CRESTs based on experience from other situations and technologies. They also play a vital role in communicating the CREST culture and philosophy to industrial affiliates. The following suggestions are provided as ways to build a trusted partnership between NSF, industry, and the CREST:

- Invite the PO to industry meetings to communicate NSF CREST culture and philosophies.
- Invite the PO to industry meetings to communicate feedback from site visit reports on items of specific importance to industry.
- Encourage industry to communicate directly with the PO if there are pressing issues, both positive and negative.
- Although preparing the industry SWOT analysis is typically a closed-door activity, the PO should be invited to help focus the discussion. This is especially important in the early years of a CREST. Depending on the circumstances, the PD might be invited to say a few remarks at the beginning and then leave, or to remain as an observer or facilitator.

To be successful and ultimately attain financial self-sufficiency, a CREST must work continuously to draw industrial firms into the highest level of interaction and then successfully interact and derive support from them at that level. NSF serves a key role in helping CRESTs reach this difficult but necessary state of being. NSF enforces regular and thorough reviews of every Center's progress in university-industry interactions. Shortfalls in progression are identified and addressed in a timely manner, with high priority. Proven techniques to address shortfalls are communicated among staff at different CRESTs, through programs coordinated by the NSF. The application of best-practice principles to any particular case is aided by the experience of the Program Officer and other NSF staff.

6-07. Summary

The perspective of the CREST's Industrial Liaison Officer is a bipolar one, which involves championing industry's views to academics as well as

representing the university Center to industry. Most ILOs find common ground in these seemingly divergent points of view, working to promote mutually beneficial interactions between partners from the two cultures. Achieving this balance requires personal and programmatic flexibility as well as diplomacy. Programs developed by effective ILOs often challenge the status quo in both the university and industry. The desire to facilitate their success and learn from their failures is the basis for the suggestions that follow.

The most important lessons learned regarding industrial collaboration are:

- Keep at it-industrial collaboration is difficult and requires continuous effort.
- Inform new members early that satisfaction and benefits accrue to those firms that interact frequently with the Center-participating in collaborative research, attending meetings regularly, making contacts, supporting students, seeking information, and giving advice.
- Trust, not a contract, is the basis of a long-term relationship. Industry wants a solid return on its investment-demonstrable, personalized value for each member company. Therefore:
- For many companies, access to valuable ideas or processes is a significant motive for joining. CRESTs must provide members meaningful access to technology on an equitable basis.
- For technology that is not appropriate for protection as intellectual property, members should be given the utmost possible chance to incorporate it in their operations.
- Industry must have a strong role in setting the Center's research agenda.

In recruiting members, especially for a start-up Center, consider the following:

- Tailor recruitment strategies to each prospect; partnership is achievable only if there is a true confluence of interests.
- Maintain frequent and direct personal communications and visits.
- Clearly state the purpose of the Center and the role of the company in the proposed Center's research and education programs. Share the plans for any characterization or instrumentation facility to be developed. Clearly state the intellectual property rights issues and proposed or developed solutions. Share the university's plans for long-term viability of the Center.

- Convince the companies that leveraging resources through Center membership provides a strong return on investment, and that the more they participate the more they will gain.
- Discuss with prospective members the uses to which industry funds are put. Also note whether overhead charges on industry contributions will be waived.
- Discuss the commitment of the university and college administration to the long-term viability of the Center.
- Create opportunities for industry professionals to interact with students and faculty in such a way that they can influence Center programs.
- Discuss Center plans for distance learning and short courses.
- Be honest about what you think the Center can do for a company, and deliver what you promise.
- Follow-up with required information.

The favorite practices developed by CRESTs to facilitate industrial collaboration are:

- Canvassing the Industrial Advisory Board for ideas on directions in research and education
- Cooperative research projects and personnel exchanges
- Student internships in industry
- Technology transfer short courses
- Using senior-level students as links to industry
- Workshops, workshops, workshops!
- Keeping a current contacts tracking database
- Developing solid metrics for assessing the industrial interaction and collecting the data.

NSF—and in particular the Program Director—serves a vital role in helping CRESTs achieving the support of both industry and universities. Simply by providing its imprimatur, the agency opens doors for the Industrial Liaison Officers, and builds support for the CREST concept of industrial-academic partnership.

Each Center is unique. What works in one may not work in another. If you find that you need more information, we encourage you to call the ILOs at one or more CRESTs-especially those participating in the Industrial Liaison Consultancy. We value corporate efficiency for the CRESTs and see no reason for anyone to re-invent wheels or not benefit from the collective knowledge of the CRESTs' Industrial Liaison Officers and CREST industrial programs.

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CREST Best Practices Manual
Chapter 7: The NSF/CREST Interface

Contents

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EDITOR'S NOTE—*this chapter is derived from the "Other Topics of Interest for CREST Applicants and Awardees" tip sheets 1-01 to 3-07.*

7-01. Introduction

While it is generally instructive to know what a 'good' CREST project looks like, of greater interest to CREST applicants is: How can I write more competitive proposals? Among awardees the specific questions include: What are the administrative requirements of my CREST award?

No Best Practices Manual can hope to provide every answer to your particular circumstances. In general, potential applicants should begin by reviewing NSF's Grant Proposal Guide (GPG) in addition to the latest CREST program solicitation. CREST awardees should refer to the GPG, the program solicitation and the specific expectations for their project, as detailed in the Cooperative Agreement.

Advice about the interface between NSF (herein meaning the CREST program and its staff) and CREST (herein meaning a given CREST proposal or award) is logically divided into three areas depending upon the status of the project: (i) preparing a CREST proposal, (ii) award administration; and (iii) award follow-up, which will be detailed in the following sections.

This chapter presents a formidable amount of information for potential applicants. It is not intended for reading all at once. Rather, the information should be browsed in a step-by-step manner according to where the applicant is in the proposal process—applying to CREST, administering a CREST award or wrapping up the CREST cooperative agreement at the end of NSF support. The information will have much more relevance if it is read when applicable, rather than scanned all at once.

7-02. Preparing CREST Proposals

As a prospective proposal writer, consider serving on a CREST panel, or consulting others who have reviewed CREST proposals in the past. This is not "inside information" but rather some good insight into the review process. This Best Practices Manual provides much of the same advice. Reviewers' comments are meant to be constructive, helping you to submit stronger proposals in the future. HOWEVER making these corrections, verbatim or not, is no guarantee of award in a future competition against other proposals and using different reviewers. Conversely, those receiving CREST awards should

not assume they may dismiss critical comments meant to improve the proposed goals or scope of work.

It is highly unlikely that any proposal is immune from improvement. Remember that the critical reviews of your proposal are not personal attacks, and not all of them will be as detailed or specific as you would like. Inappropriate comments from reviewers are not tolerated and do not factor into award/decline recommendations. However, once the reviews are released to the PI via FastLane, you may contact the CREST program staff for clarification. You should also strive to make the reviewers' task 'easy' by checking the proposal for completeness, alignment with program goals, and clerical (budget figures, spelling, support documents, complete citations and references) consistency, then make the reviewers' task 'hard' to turn down your proposal for non-academic reasons.

Once you have read the BPM are ready to prepare a proposal for submission to CREST, refer to the following checklist:

- *Confirm your status as a minority-serving institution*—Ensure that your institution qualifies for CREST as a minority-serving institution, as defined. If you are unsure about this status, consult the minority-enrollment data of the U.S. Department of Education's Office of Civil Rights (http://www.ed.gov/about/offices/list/ocr/edlite-minorityinst.html). If you are not a minority-serving intuition, your proposal to CREST will be returned without review.

- *Consult the current CREST program solicitation*—Objectively compare your idea to the current CREST program solicitation. Is CREST the appropriate program for your institution and the institution's research and education communities?

- *Evaluate your local community*—what partner institutions, key staff, industry links and other CREST components are available and willing to demonstrably support your CREST proposal?

- *Do a cogent needs survey*—Once you have defined the core and satellite components of your CREST alliance, conduct a needs survey for the proposed CREST. What are the known participant demographics? What are the expected outcomes? How will your CREST uniquely benefit your institution(s)? The research community? The national interest? From where will participants be drawn and what opportunities exist for those enrolled in and "graduating" from the proposed CREST? Be specific and realistic in deriving the costs and benefits to your institution and the surrounding community.

- *Confer with current CRESTs*—The currently supported CREST Centers can be browsed at any time on the CREST program page. New CRESTs are not expected to be "cookie-cutter" duplicates of existing Centers—this is discouraged, in fact—but a wealth of common sense can be derived from PIs who have received a CREST award and are now discovering on a daily basis how proposed ideals compare with reality. Begin your information with CRESTs in your region, or Centers specializing in your particular research area.

- *Gauge community buy-in*—It is worth admitting up front that federal support cannot continue indefinitely. Project momentum and autonomy depends upon community support, and the nature of your proposed alliance should consider this when proposing and solidifying CREST alliances.

- *Conduct pilot studies and partnerships, as appropriate*—You may also want to consider testing some aspects of your proposed CREST prior to submitting a proposal. At a minimum, this will be a learning exercise that will demonstrate community motivation even without federal support. Such factors also often contribute to a stronger proposal.

- *Sufficiently document CREST preliminary support*—while ironclad agreements may be difficult to establish at the pre-proposal stage, a stronger proposal will result from detailed letters of support and finite commitments from partner institutions and key personnel.

- *Confer with CREST staff*—CREST program staff are always available to provide advice on specific questions about prospective CRESTS. However, consult this guide for the most complete information.

- *Double-check your proposal*—Using the CREST program solicitation as a guide, ensure that all components of the proposal are prepared, that the document has been checked for grammar, spelling, and budget consistencies, that all necessary sponsored projects office (SPO) and institutional review board (IRB) are completed or documented or certified as in-process, and that all biosketches for key personnel are up-to-date.

- *Test the .PDF conversion of your documents*—since submitted documents are converted to Adobe Portable Document Format (PDF), you may wish to check that all materials to be submitted (especially tables and figures) convert accurately and legibly.

- *Use FastLane*—Since 1999, all NSF proposals are required to be submitted electronically via FastLane (fastlane.nsf.gov). Before clicking the send button, consult the above checklists once again, and ensure that page 2 of the cover page is electronically signed by your institution's designated official.

7-03. Merit Review

Once you have done a needs assessment in your institution or community, have read the CREST program solicitation and are familiar with the stipulation of NSF's *Grant Proposal Guide*, it may be informative to know what happens to a proposal once it is submitted to CREST.

At the time of the panel, typically about 4 to 6 weeks after the deadline for full proposals, Center reviewers convene at NSF. They will each have formulated an opinion (or *rating*) of the proposals they have read (ranging from Poor to Excellent on a five-point scale), and will be able to read the individual reviews for all research projects linked to each Center proposal. For their part, research-project proposals are generally sent out by mail for expert reviewers in those particular fields.

Based on merit-review criteria designated by the National Science Board (see Attachment 7-01), panel deliberation then proceeds based on the following parameters—

- The strengths of the proposal's intellectual merit
- The weaknesses of the proposal's intellectual merit
- The strengths of the proposal's broader impact
- The weaknesses of the proposal's broader impact

Where "the proposal" means the collection of research-project proposals and the Center proposal tying them all together. From this deliberation, the panelists provide NSF staff with an overall review of each CREST proposal *in toto*, including an overall appraisal (or *ranking*) of Highly Competitive, Competitive, or Not Competitive.

Following the panel and based on the availability of program funds, the panelists' comments as well as follow-up information requested from the PIs is used by CREST staff to make award recommendations to NSF's Division of Grants and Agreements (DGA). In due course (typically within six months), DGA makes its decision on which of the program's award recommendations will be funded and a Cooperative Agreement for the CREST is drafted.

As a proposal manager, step back from the details of your proposed CREST and look at it with a "broad view," not just from a regional perspective but also a national and international perspective—in other words, look at it the

way an objective, critical reviewer will. Then take another look at the CREST program solicitation. Are the CREST's proposed goals and objectives aligned with those of the program? Remember, addressing the program solicitation's guidelines does not mean a parroting back of the same, vague terminology. Rather, your unique and supportable argument—that what you propose fulfills all or most of the program's goals—is what ultimately makes a strong proposal. If you honestly determine that your ideas are not a good "fit" with CREST's programmatic intent you owe it to your partners, look for other, more appropriate funding opportunities.

Also ask:

- Is the *intellectual merit* of the proposal stated in the project summary or otherwise readily apparent? How will the proposal be read by those familiar not only with the state-of-the-art in the specified research areas, but also in the realm of education and the management of large research centers?

- Is the *broader community impact* of the proposal stated in the project summary or otherwise readily apparent? That is, is diversity (gender, ethnicity and ability) represented equitably? Does the proposal have the potential for national or international impact? Does the proposal have the potential to become autonomous after federal support is withdrawn?

- Does the proposal have a unifying research focus? That is, do the various research components complement each other, and interface easily with the Center coordinating them?

- Have obvious financial, logistic, and other "flags" been addressed in the proposal's narrative?

- In the short term, will the project be able to show demonstrable outcomes?

- In the long term, is the project consistent with institutional goals and trends in the proposed research area(s)?

Now, as an editor or administrator, put yourself in the shoes of an NSF merit reviewer, who must read a dozen or more CREST proposals, and may have done so for many years. Nothing frustrates such a person more than a "sloppy" proposal. This means more than spelling and grammar:

- Are exhibits and figures properly labeled?
- Is the budget accurate and complete?
- Is the size of the proposal (from narrative pages to dollars requested to proposed months) within the specified parameters?
- Are factual references consistent throughout the proposal?
- Are all references cited?
- Are all pertinent biosketches, CVs, letters of support and other materials present?

Does the proposal have a lot of complicated tables and figures? If so, you may want to try converting them to Adobe Portable Document Format (.PDF) before sending through FastLane, just to make sure your message isn't garbled. Make sure you are familiar with the use of FastLane for complex, multi-component proposals. If necessary, contact the Administrative Director of a current CREST for tips to help ensure all the pieces of your proposal transmit properly.

Reviewer Confidentiality—All NSF merit reviewers must sign a declaration of confidentiality and confirm the absence of conflicts of interest about the content of the proposals they read or hear discussed by others in the review process (detailed in NSF Form 1230-P, attachment 7-02). At the same time, though PIs can access verbatim copies of the text reviews their proposal receives, the identity of the reviewers is kept confidential to NSF. PIs are also welcome to suggest reviewers for their proposals at the time the proposal is submitted to FastLane, but it is at the discretion of the CREST program officer which reviewers are assigned to each proposal.

While reviewers do not always know which proposals they will receive for review, or what the specific content of those proposals might be, they are expected to notify CREST program staff of any conflicts as soon as these are discovered. The proposal is then reassigned to another reviewer of equivalent expertise.

Even given NSF's rigorous expectation of anonymity, the community of experts in some fields may be limited to a few, well-qualified researchers. In highly specialized areas, there is always the potential for similar ideas to arise independently and apart from any given proposal with or without NSF

review. NSF takes the above declarations made by reviewers—whether in person at the panel or via FastLane certification—most seriously, and will investigate breaches in this process. The Foundation's Office of the Inspector General is the unit in charge of investigating allegations of intellectual impropriety.

Nominating Reviewers—PIs may suggest names of potential reviewers for their particular proposal. Obviously such persons cannot be directly associated with your proposal, should not benefit from a potential CREST award, or have any other potential conflicts of interest with it. It is noted that highly specialized fields may have a particularly limited number of qualified reviewers—conversely, if the field is too obscure or specialized, or the suggested reviewer is not active in the community or well versed in the area discussed, the proposal may be disadvantaged in assessments of broader community impact or developments in the national interest.

Most commonly, CREST program staff recruit potential reviewers from past CREST panels, panels of similar NSF and other programs, contact databases and personal contact at conferences and meetings. Referrals are welcome anytime, but the best time for suggesting potential reviewers is within a month or so of the annual proposal deadline.

Panelists who provide good constructive criticism, contribute to the group discussion and keep a national perspective on the CREST award process are often invited back. Panelists are also invited to recommend colleagues that may assist CREST proposal review on later panels. For their time, panelists receive paid return travel and accommodation, as well as a per diem for the duration of the panel. Ad-hoc or mail reviewers are generally not compensated for their service since travel is not expected. Per diems for mail reviewers are not usual but may be considered in exceptional cases. Reviewers may also request that NSF send a letter of acknowledgement to their supervisor or institution, in appreciation for their time and contribution.

Many PIs find the merit-review process (particularly panel service) to be an informative and interesting experience. Disparate opinions and perspectives from all around the country are brought together, with invigorating academic discourse. Friendships and contacts are often made between panelists from very different disciplines, who might not otherwise have had a chance to meet professionally and now get the chance to "make a difference" on a national scale. "If I'd only known how the review process works before I submitted my last grant!" is a common observation. However, per the

reviewer confidentiality agreement (see attachment 7-02), specific intellectual information "learned" while on panel service cannot be applied to future proposals.

7-04. Frequently asked questions (FAQs) by CREST applicants

Once you have browsed this list, as well as the information in the preceding section, you should be well briefed on what makes a good CREST. Of course you may still have other questions, or may wish to suggest a new "FAQ" for this manual. In that case, you are welcome to contact the CREST program directly.

Does my institution meet the minority enrollment eligibility requirement?—A good place to find this out is your institution's registrar's office or the office of the president. You can also check your institution's minority enrollment data with the data of the data of the U.S. Department of Education's Office of Civil Rights (http://www.ed.gov/about/offices/list/ocr/edlite-minorityinst.html).

How many research sub-projects are required for a competitive proposal?—This will depend largely on the type of institutions proposed, the scope of work and the specific area of research being addressed. In general this means "more than two or three" (i.e., far more than scale and complexity of a typical research grant) but "fewer than ten," which would be unwieldy to administer and may lose the appearance of a coherent research focus. Typically, CREST proposals include 4 to 6 sub-projects, but any such number should be in line with the scope of the project and a cogent needs survey. The association between research projects and Center activities should be complementary. They should not look patched together or overly complex for the proposed budget and timeline.

How can my university demonstrate institutional commitment with the proposed CREST Center?—Solid letters of support are a good start. These originate in the office of a senior official at the institution and should provide specific assurances rather than vague promises. Assurances may include mention of dedicated space, equipment or other facilities, support for faculty taking time to assist the Center during its startup, financial commitments or other concessions. It is always more desirable to show your institution is already doing some of the king of team-oriented, multi-disciplinary research and education that would gain even more momentum from CREST, rather than giving the impression that nothing can or will be done without the receipt of CREST funds.

Can you provide an example of a CREST Center management structure that provides project oversight and well as day-to-day management?—This manual details many of the components of a successful CREST or

Engineering Research Center, particularly the need for a solid strategic plan and committed leadership. Whoever, this is not intended as a recipe or a filter for alternate management scheme. One you have read the BPM and these fact sheets, you may wish to contact current awardees with projects similar to the one you propose. Chances are, they will have tips for potential pitfalls and suggestions for good practices especially applicable during the infancy of a new CREST.

How can a proposed CREST center demonstrate synergy among the research sub-projects?—The CREST Best Practices Manual outlines the importance of a strong research plan that is complementary to the Center's strategic plan and day-to-day administration. Sub-projects should complement each other without redundancy or duplication. Their means of intellectual and financial reporting, cooperation on education programming, and partnerships with other units inside and outside the CREST all valuable things to note in your proposal.

How can a CREST center expand research opportunities for students?— CREST faculty should be committed to the research opportunities for student. These can be augmented by such things as faculty incentives for research assistantships, contacts with industry for student internships, job fairs and student research conferences, outreach to K-12, and events with local science attractions, national labs and research facilities.

What are some examples of in-kind cost-share?—See above comments on letters of commitment, office space, faculty incentives and research experiences.

How should project performance be evaluated?—Alignment to the CREST's strategic and research plans are a good start. Are goals and objectives fulfilled on time and on budget? Are financial records in order? Has there been good communication with the CREST and the other sub-projects? Last but not least, has the project made an impact in its areas of research focus via patents, publications, and presentations made an impression on its area of research as well as education about this area?

Who should serve as Center PI? As Co-PIs?—See Chapters 2, 3 and 4 of this manual.

7-05. Award Administration

As the saying goes, be careful what you wish for because you just might get it. Certainly a CREST award is an exciting opportunity to enact real changes in institutional culture. But with substantial funding comes a proportionally larger amount of responsibility and accountability. This is the first in a series

of fact sheets to familiarize new PIs with their CREST responsibilities and obligations.

While you are not obligated to commit extensive funds and resources prior to the onset of your award, this is not the time for being idle. Year 1 of your CREST begins as of the award start date specified on the project's Cooperative Agreement, if not earlier. By this time, key staff and procedures should be in place and ready to begin with a clear outline of the expectations from them.

- In all matters, the Cooperative Agreement and the project's strategic, research and administrative plans should be your primary guidepost.
- Review "baseline" conditions (i.e., the state of affairs, research productivity, student demographics, etc., immediately before CREST funding) and document these.
- Review your "lessons learned" since the time your proposal was awarded—if not before—and begin applying these as of your award start date. Delays due to staffing, new construction, or other unexpected events do not change the fact that your award has started and a Year 1 report will be expect in about 365 days.
- Work collaboratively with your Research and Administrative directors from Day One to ensure clear lines of communication, tracking time and financial expenditures, and reaching project goals.
- Project outreach is not something that should wait for interesting outcomes. "Marketing" your CREST began with the first draft of your proposal. Keep the momentum going. The onset of funding only means you can be more strategic (and must be more accountable) for your outreach.
- Expect some start-up problems and delays. However, don't use these as an excuse to adopt a "learn as we go" mindset. Plan the work and work the plan.
- Remain aware of the kind of data, outcomes and other metrics for progress mentioned in the Cooperative Agreement and in your project plans. These are the data NSF and other auditors will be expecting to review. The sooner these metrics are tracked, the better.
- Remember that not all reported information (to NSF or among project staff) is likely to be good news. Reporting all information—good and bad—at the time this is noted can lay the foundation for resolving these problems later in the project.

Administratively, he major financial and personnel accounts for the CREST should be set up and ready to go on the start date specified in the Cooperative Agreement. Plan on regular meetings with the Executive and

Research directors to ensure everyone is "on the same page." Set a schedule for administrative reporting and the content expected in those reports. Establish up front which data will best capture the progress and activities of the CREST relative to the project's strategic plan and the Cooperative Agreement and track these data. Keeping daily or weekly journal notes will help compose quarterly or annual reports later.

7.06 The Cooperative Agreement

The Cooperative Agreement—Recall that the *recommendation* to award your proposal by the NSF program officer is not yet an *award decision*. The award is not actually made until NSF's Division of Grants and Agreements (DGA) confirms it. The key word here is *agreement*, since every grant is really legal obligation for the PI to deliver what he or she was funded to do. In the case of significant (more than $2 million and 36 months' duration) NSF awards, procedures are usually initiated to prepare a detailed Cooperative Agreement (CA) between NSF and the host institution.

The Agreement varies somewhat from program to program, but essentially it helps to insure NSF's significant investment in the project by itemizing the things for which the project will be held accountable. The CA is therefore scrutinized very carefully by the program, by DGA and by the host institution in the weeks and months after a proposal is recommended and prior to the commitment of funds.

Typically the CA will contain two types of content: (i) Specific deliverables, goals and other expectations, as drawn from the proposal, merit review, the program officer's recommendation and follow-up discussions with DGA and the PI; and (ii) More generic legal text stipulating the terms of the CA and penalties for breaching the agreement.

The CA, side-by-side with your strategic plan, provides the legal and intellectual guidelines for your project. Apply them accordingly. Remember that you have been funded for what was proposed, approved by merit review and negotiated in the CA. The CREST is no longer a "learn as you go" enterprise. Significant change in scope, timeline, budget and key personnel must be confirmed (at the time of their occurrence) by the CA and only after consultation with the NSF program officer. The NSF program officer, not the PI, is usually the direct interface with DGA in matters regarding the CA and amendments to it.

The project's administrative director should consult the CA regularly along with the CREST's management plans to see that the expectations for deliverables and performance goals are being met. Bring deviations from this to the attention of the CREST Director and implement corrective measures. The CA will usually also stipulate when site visits and reverse site visits will be required, obligations to attend NSF events (such as the annual awardees' meeting), panel service requirements (if any) and other administrative details. Use these parameters to plan your reporting obligations accordingly, maintaining clear schedules and lines of communication between the administrative director, the executive director and the research director.

7-07. "Changing Institutional Culture"

The significant financial and time investment that NSF is making in your project has, among other desirable benefits, the potential to change the institutional culture of the host institution and its allied partners. But what does "changing institutional culture" mean in terms of measurable differences and successful award administration?

Beginning with the CREST support garnered during the preparation of your proposal, contacts with CREST partners on and off campus should be formed with a long-term perspective. No funding can last forever, but there is little reassurance in building something that will become a non-productive "white elephant" after support ends. What remains long after funding is the institutions commitment to excellence in research and STEM education.

Your proposal and any needs assessments you have drafted should give you a detailed, quantitative "snapshot" of what your campus was like prior to CREST funding—faculty attitudes and productivity (publications, patents, etc.), student attitudes, demographics and major, plans for facilities, industry partnerships and other academic parameters. This baseline (pre-CREST) appraisal is the best way to measure CREST impact.

Good feelings and intentions are all well and good, but they are insufficient for measuring the CREST's impact. Quantitative metrics for gauging short- and long-term impacts are an essential part of the strategic plan. Often, they are also stipulated in the Cooperative Agreement. Consult these on a regular basis to ensure you are hitting your marks. Confer with your key staff, including the NSF program officer on shortfalls as soon as they are noted.

A large infusion of cash and the prestige of an NSF grant can do much to change the prevailing mood in a given department—but this is not true

institutional change. Cultural change requires long-lasting, measurable differences (ideally, but not always, improvements) in how the institution views research and education and conducts business in these areas.

q Baseline data should be consulted and updated at least annually during CREST funding. Longer-term impacts may only be evident in later years but can still be measured and reported to NSF via amended project reports.

Administratively:

- Schedule meetings with the Executive and Research director to ensure project goals are on target and the right data are being collected.
- Regard data collection with vigilance. Long after the project personnel have moved on, these data are the best record of what went on, and why. Don't limit yourself to tracking only those things NSF may have an interest in. The PIs, faculty, industry partners and other stakeholders may have other like-to-know data. Accommodate them to the extent that it supports the CREST's strategic plan.
- Keep your records in order. A "shoebox" filled with five years' worth of "CREST impact" is not as useful as regular (semi-annual or quarterly) reports summarizing all of the CREST's "vital signs." Such reports also facilitate the preparation of annual and final reports to NSF.

7.08 "World-Class Research"

The NSF *Strategic Plan*, as stated, supports—"a diverse, competitive and globally engaged STEM workforce and well-prepared citizenry." CREST projects, by their nature, are nearly an archetypal response to this mission. By virtue of their support of underrepresented minorities and the research and education capacity of minority-serving institutions, *diversity* is built in. *Workforce* development in STEM is related to the production of *competitive* (professionally qualified) graduates in science and engineering fields. A well-prepared (here meaning, science literate) *citizenry* derives from successful dialogs with the community about CREST project missions, activities and outcomes. Last but not least is *globally engaged*, which speaks directly to international awareness, collaborations and respected contributions to the knowledge base.

Your proposal and strategic plans should have identified the state-of-the-art in one or more research areas providing a central focus to your CREST. It is doubtful that this condition exists *in toto* within the United States. Cognizance of the global state-of-the-art and where opportunities for contribution and collaboration may exist, should be a fundamental part of

Executive and Research management of the CREST. Keep in mind that your operational activities should focus on the preparation of the U.S. (domestic) workforce, but that quality preparation must include exposure to and interaction with international centers, teams, and individuals.

World-class research means academic respectability abroad. Will your CREST be known as an international center of excellence in your chosen area of research? Will it be a "go-to" resource for investigators from around the world? Is your market strategy facilitating this reputation? If/when your CREST becomes a world-renown resource, will you be able to accommodate international attention? Are your researchers participating in international meetings, hosting experts from abroad, participating in international research teams and publishing in peer-reviewed international journals? Are your education programs hosting international students and exporting the Center's knowledge contributions to students in graduate study, undergraduate study, K-12 and internships? What does the Science Citation Index suggest about the research efforts of your CREST? These are the kinds of issues the CREST research director must continually review.

As much as possible, international collaborations and activities should be tracked and reported. One way of looking at it is, the education and faculty development aspects of the CREST should operate domestically, contributing to "a diverse and competitive" workforce, while the CREST research activities operate internationally and should be "globally engaged" and respected. Of course, the exchange of experience and good practices between the foreign and domestic activities is expected. Data collection and reporting should be able to quantitatively address the diversity (student demographics), competitiveness (graduation rates, employment, publications, patents, presentations, conferences attended) and global engagement (international activities) of the CREST—at baseline levels as well as while the CREST matures and becomes autonomous.

7-09. Site Visits and Reverse Site Visits

Site Visits—A *site visit* is usually not as informal or as simple as the term implies. Typically it involves hosting a small group of objective delegates appointed by NSF to have a look at the CREST's activities "on the ground." Site visitors, who may or may not be accompanied by the program officer, will then report their findings to NSF. Unlike a reverse site visit (see below), which is usually scheduled well in advance and stipulated on the Cooperative Agreement, site visits are initiated at the discretion of the program officer,

though ample time is still given for the CREST to prepare for site visitors. Usually, though not always, site visits are instigated to address and resolve specific areas of administrative or managerial concern.

- Contrary to some opinion, a site visit is not an audit. While site visits are sometimes scheduled in response to specific administrative concerns, usually the event is designed to provide quality information about the CREST to NSF and constructive advice to the CREST from experienced knowledgeable observers.
- The "look and feel" of the CREST is important, but the business of how the CREST is doing should be the focus of the site visit agenda. SWOT (Strengths, Weaknesses, Opportunities and Threats) analyses are common. PIs should consider these in advance for all major components of the CREST.
- Put yourself in the shoes of a site visitor. What might you want to know to form an honest appraisal of the Center's progress? Specific and directly impacted by the CREST:
    - What are the specific faculty numbers and demographics? Their familiarity with the CREST and its mission
    - What are the student numbers and demographics? Their familiarity with the CREST and its mission
    - Reports from the CREST's research projects.
    - Updated lists of patents, publications, presentations, including full citations. How do these compare to baseline o pre-CREST data?
    - Changes to the strategic plan? Reasons for this?
    - Changes to staffing or university leadership? Reasons for this?
    - Updated financial account reconciliation, submitted expenses, expected expenses?
    - Lists of outreach efforts and publicity (include full citations)
    - Post-proposal endorsements/criticisms from industry partners, university leadership, evaluators and external reviewers/advisory boards?
    - Self-identified project highlights?
    - Self-identified areas of concern?

The site visitors' time is valuable and expensive. Offering them reams of data to read only once they arrive is not a good use of this opportunity. Consider having the most essential materials prepared 2 to 3 weeks in advance, then sending this information to the site visitors, via the NSF program staff if necessary. The NSF program officer should also receive a copy of these

materials. (Site visitors are usually briefed with the latest CREST program solicitation, your project's original proposal and copies of all project reports submitted via FastLane. Copies of these materials should be provided.) The agenda should provide ample time for meetings and presentations. Copies of the materials provided for advance review should also be on hand. It is likely that NSF or site visitors will have specific questions for CREST personnel and will provide a list of these issues in advance. As much as possible, your advance-review materials should focus on these specific issues against the broader portfolio of your project's activities.

You are not expected to "wine and dine" the site visitors. As representatives of NSF, they are expected to pay for their own meals and are not permitted to accept gifts or gratuities. Reception functions, if any, should be scheduled outside of normal business hours.

Typically, the site visitors will file their report to the NSF program officer and s/he will follow-up with the CREST Director. Finally, all correspondence related to the site visits, the agenda or the resulting recommendations should be retained.

Reverse Site Visits—A reverse site visit differs from a site visit in two ways: (i) It is usually required via the Cooperative Agreement and is planned to coincide with the mid-point of the CREST; and (ii) The site visitors remain at NSF while a delegation from the CREST gives a presentation of Center activities at NSF. Often, all awardees from the same CREST cohort are given reverse site visits at about the same time: mid-way through the Agreement, after the Center is established and before it begins planning for phase II support or, alternatively, winding down operations.

NSF program staff will convene the meeting and set the agenda. A panel of experts will be there to listen to the CREST team's presentation and ask pertinent questions based on the CREST's past activities and future plans. As with site visits, the panelists' recommendations to NSF intend to provide constructive criticism to the CREST staff and management.

A reverse site visit is more of a "tell" compared to the "show" of a site visit. Nonetheless, the audience and the intent of the meeting are much the same. Consider that you will be away from your home institution during the reverse site visit, but you will need to access much of the same information as required during a site visit. This information must therefore be made portable for travel. Being prepared with "the facts" will lessen the amount of follow-up

required for the reverse site panel to formulate their conclusions and recommendations. If stipulated in the Cooperative Agreement, travel to the reverse site visit at NSF (or another, mutually agreed upon location) is at the expense of the CREST grantee.

As with site visits, the panelists' time is valuable and limited. Consider having the most essential materials prepared 2 to 3 weeks in advance, then sending this information to the NSF program staff if necessary. The NSF program officer should also be given a copy of these materials. Specify what audio-visual needs (e.g., VCR, DVD, laptop, 35mm or LCD projector) you will need to support your presentation at NSF. It is likely that NSF or site visitors will have specific questions for CREST personnel and will provide a list of these issues in advance. As much as possible, your presentation materials should focus on these specific issues against the broader portfolio of your project's activities. Typically, the reverse site panel will file their report to the NSF program officer and s/he will follow-up with the CREST Director. All correspondence related to reverse site visits, travel documentation, the presentation data and the resulting recommendations should be retained.

7-10. Project Reporting

Annual project reports—Annual project reports are due at roughly twelve-month intervals from the start date of the CREST award, as stipulated in the Cooperative Agreement. They must be submitted via FastLane and must use the on-line template for annual project reports provided there. Admittedly, the FastLane annual report template is not the perfect fit for all NSF programs or projects. But it is to be considered the *absolute minimum* information expected from the PI on an annual basis. Much more information can be provided by the PI or may be requested at the discretion of the program officer.

- Do not wait for remarkable results or a convenient point on the project calendar. Annual reports are due roughly each 12 months from the award start date. Failure to provide acceptable annual reports in a timely manner may result in the relay or suspension of forthcoming grant increments or other disbursements.
- Promote the mindset that daily or weekly journal logs will greatly facilitate the compilation of annual reports.
- Work collaboratively with your Administrative and Research directors to ensure that all components of the CREST are represented.
- As summarized in the HRD guide, *Tell Us a Little About Yourself* (attachment 7-03), annual reports need not contain all "good" news.

Measurable outcomes, deliverables and project participant demographics are preferred to vague reiterations of goals and objectives.

- It is expected that the PI will use the FastLane report template verbatim, inserting “no measure” where no data are available. Composing a unique report format, then populating the FastLane report with references to “see attachment” is not acceptable practice since appended text cannot be data captured for content analysis.
- An “annual” report will apply only to the activities and outcomes of the preceding 12 months (for Year 1) or the 12 months preceding the annual report (for Years 2+) with no gaps or overlap in the annual reporting interval. Keeping a running total of activities and resubmitting updates with the same history year-to-year is not acceptable practice.
- If in doubt about our project’s annual report due date, check the award start date on the Cooperative Agreement. You will likely not be prompted for the report by the NSF program officer until it is already overdue.
- Recall the earlier advice to try pre-testing the .PDF conversion of tables, figures and other report elements that may be garbled or rendered unreadable by submission through FastLane. Don’t presume that NSF will contact you to correct such errors.
- Double-check the dates specified and “annual report” selection with the toggles in FastLane and compare these to the specifics of previous annual reports before submitting the report. Again, there should be no gaps or overlap in annual reporting intervals.

Financial reports—Financial reports go hand-in-hand with reported outcomes and activities. Together they provide information on how well the project is doing, whether it is on time/on budget, and whether the proposed scope of work.

In general, the proposed budget is negotiated as part of the Cooperative Agreement. This process is some combination of (i) the requested amount; (ii) available program funds; and (iii) budget narratives/justification and follow-up information from the PI.

Once the project budget is “set,” funds cannot be arbitrarily re-assigned. Participant costs, in particular, may not be reduced. In some cases, *minor* amounts may be reassigned within the same line item without penalty. But in general, any proposed changes to the project’s budget, scope of work or key personnel must be approved by NSF. Your program officer or DGA will then work with you to administer the proposed change properly.

Be advised that any substantive shortfall or excess of unobligated funds not previously reported to the program officer will likely trigger a request for further justification or details. Significant amounts of excess unobligated funds may result in the delay or suspension of the next award increment. In all matters related to the CREST, temporal (timeline) accountability is just as important as financial (dollar) accountability. Each helps to establish that the CREST is doing what it said it would in the manner the merit review and program recommendations have determined it should.

Financial reports related to CREST are of two types: (i) financial account balances related to the CREST and its respective sub-projects; and (ii) declarations of unobligated funds on annual and final FastLane reports. The former type is what is examined by site visitors and auditors; the latter is usually summarized as a brief statement or justification on the annual report.

Particularly for CRESTs that have components spread over a wide geographic area, it is strongly suggested that the CREST have its own financial accounting system and that all components of the CREST are required to abide by the same reporting methods. Of course the financial reporting system must abide by all accounting requirements of the host institution(s) as well as any requirements for financial reporting stipulated in the Cooperative Agreement.

Other reporting obligations—Annual reports and financial statements comprise the majority of your project's reporting obligations to NSF. However, NSF program officers are often asked to provide additional or more detailed information about project outcomes, such as numbers and demographics of participants or highlights specific to the Government Performance and Results Act (GPRA). Often the need for this information is not known in advance and must be produced on a deadline. Anticipating what kind of information is sought and the form in which it is needed can help get information about your project reported in many kinds of publications.

You can reduce the likelihood of needing to provide more information be ensuring that the information you provide on your annual reports is complete and up to date.

- Consider adding links to late-breaking news, highlights and current lists of publications, patents and presentations to the Web site of your CREST. Notify your program officer that you have done so and keep the lists up to date. NSF or others can then retrieve the information without needing to repeatedly contact project personnel directly.
- Don't assume that an approved annual report is beyond improvement. Maintain a good rapport with your program officer. Ask whether your latest reports are exemplary, just sufficient or in need of improvement. Maintaining this line of communication will help NSF highlight the most from its awards.

- Keep all reports to NSF on file (FastLane does this automatically, within limits) to provide a record of what you have said about the project. Periodically review the content, syntax and focus of these reports to see if they truly reflect the project's latest activities and its strategic plan.

7-11. Media Relations

Shelves of reference books and entire curricula have been devoted to media relations and strategies for getting publicity for one's work. Duplicating or furthering such advice is far beyond the scope of the current discussion but there are some general approaches you can apply to your day-to-day CREST activities.

- *Get on with it*. Promotion and information dissemination about your CREST shouldn't wait for a sufficiently big "Eureka!" moment, or applied as an afterthought with residual funds in the final year of your award. Whether you realize it or not, marketing your CREST began when you started writing the proposal.
- *Build long-term relationships*. It bears repeating that not everyone will buy-in to your CREST vision exactly how and when it best suits you. Promote the idea that the CREST is a vital, lasting part of the community and be your own best ambassador for noting CREST highlights.
- *Be familiar*. The university president, dean's office, media relations and student union should all know you're in the neighborhood and what you're doing.
- *Be evergreen.* It's unrealistic to expect a reporter to ignore existing deadlines to write up your latest time-critical result. Put forth story ideas that will be relevant for some time after the fact and appropriate for stories under an array of editorial theme and tone. If your budget and mission allows for marketing materials (posters, brochures, CD-ROMs, print ads), make sure funds are not squandered on one-use- or one-time-only items or excessive production runs.
- *Be accessible*. Even while pursuing cutting-edge research, it's essential to make what you're doing understandable and relevant to the general public. Don't expect someone to read your latest journal publication and give sing its praises to the masses verbatim.
- *Advertise*. A compelling Web site is a start, but it is still a passive approach, requiring people to find you. As the budget permits, consider a weekly seminar or social or a quarterly newsletter or e-bulletin open to anyone. Keep a list of people who want to hear more about your progress and recognize when this offers opportunities to highlight the CREST as a member of the community.
- *Open your doors*. Offer tours to reporters and photographers even when you're not "looking for something." Show new industry partners

what they could subscribe to. Do presentations in local schools and invite the local newspaper to come along.

- *Be clear*. Not everyone needs to hear all the good things about your facility. Stay on message, provide engaging sound bites and emphasize the usefulness of what your Center is accomplishing. Let people "drill down" in your expertise to their own level of comfort and understanding.
- *Look around you*. Students come and go through university classrooms and laboratories every day. Your CREST staff will likely include part-time employees and students. Let them see the rewards of what the CREST is doing and be enthusiastic about it. Some of these witnesses may become scientists themselves. Most become other things, including reporters, business owners, parents, voters, legislative assistants and policymakers. It's in your power to directly affect what they "know" about science from even a passing exposure to your work and a look at how your CREST looks at discovery.
- *Look beyond NSF*. Never forget that the CREST must become a valued and appreciated part of the community. It's the only way that the CREST will achieve the kind of roots to the community that will carry its mission forward long after NSF funding has ended.
- *Track your progress*. Note the Center's publicity and media exposure by keeping clear records. Site visitors, reporters and NSF program staff alike have an interest in such things. Keep a list of full, searchable citations and scanned articles as an electronic clipping file. Track which outlets seem to yield the most comments or callbacks for more information. What kinds of secondary outreach would be useful in these areas?
- *Communicate*. Relay the observed trends and opportunities among the Center's directors and see which offer the best fit with the Center's strategic plan.

7-12. FAQs of CREST Awardees

CREST program staff encounter a number of frequently asked questions (FAQs). For the purposes of these fact sheets, such questions have been partitioned into lists most applicable before, during and after award. These are the most common questions, and the answers provided are given in the name of consistency for all applicants and awardees. Once you have browsed this list, as well as the information on the preceding fact sheets and the CREST Best Practices Manual, you should be well briefed on what makes a good CREST. Of course you may still have other questions, or may wish to suggest a new "FAQ" for these pages. In that case, you are welcome to contact the CREST program directly.

What are some guidelines concerning allowable and non-allowable costs?-- [this section currently under revision]

What are some adequate mechanisms to capture time and effort reports for project staff?-- [this section currently under revision]

What are some recommend processes that allow evaluation findings to inform project performance?-- [this section currently under revision]

How can performance be measured consistently in each of the project components?-- [this section currently under revision]

What is the role of the External Advisory Committee?—The EAC is foremost a reality check that the CREST is proceeding in its administration, education and research objectives (as is the Internal Advisory Committee or Steering Committee). Beyond that, the EAC serves as an objective evaluation body for the CREST. It seeks to get beyond the “politics” and “tunnel vision” that may develop in any large project and help ensure that CREST’s research activities are still aligned with national and international interests of the research and education community beyond the stipulations of the CREST Cooperative Agreement.

What is the role of the Center PI?—See Chapter 2 (Executive Management) of the Best Practices Manual.

What is the role of the Center steering committee?—See Chapter 2 (Executive Management) of the Best Practices Manual and the above comments on the External and Internal Advisory Committees.

How can we prepare for an audit?—The kinds of materials that NSF prefers to inspect during audits, site visits and reverse site visits are detailed above. Other materials may be specifically requested by the auditors and the project staff would do well to ask the auditors for any specific materials they would like to see. In general, all project accounts should be reconciled. Supporting documentation (justification) for questionable expenditures should be available. Project deliverables and financial records should be up to date.

7-13. Award Follow-up

The end of an award is a time of relief for some and a time of anxiety for others. Usually, the difference between the two depends on how well you have prepared for this time administratively and in terms of building project

momentum aside from NSF funding. If you have followed the advice in previous sections, your CREST may be a self-sustaining entity and a world-renown authority in your area off research (and education about that research). On the other hand, the project's momentum may be such that a phase II CREST proposal is warranted to continue the achievements made so far. Whichever the case, your obligations to NSF do not simply end when the end date on the Cooperative Agreement is reached.

This is not the time to drop everything and cease operations. In some ways, you should have been preparing for the end of funding for the past five years. Now is the time to wrap up certain aspects of the project and continue the momentum of other aspects. It is also probably the best opportunity since your pre-proposal needs assessment to survey the landscape, "take stock" of everything the CREST has accomplished (whether good or not-so-good) and make sure these things are fully documented. This is the time to work especially closely with your directors of research, education and administration. Ask them:

- Have all outcomes and activities been fully recorded and reported?
- Are lists of the number and demographics of direct participants up to date?
- Are research outcomes (patents, journal articles, presentations made or pending) up to date?
- Are publicity clipping files up to date?
- Have all receipts pertaining to the award been submitted?
- It is a good idea to prepare auditable summaries for all of these areas for your own reference. Then, a final project report is due via FastLane within 90 days of the end of the Cooperative Agreement. Failure to provide this report in a timely manner will result in an overdue report 'flag' attached to all key personnel on the project that may delay the review of any future proposals submitted by the institution or these individuals.

Whether this is the end of your CREST support or the beginning of a phase II award, it is an excellent opportunity to wrap-up the books on phase II.

- Are all financial accounts spent out and reconciled with all receipts submitted?
- Have unusual expenses been fully justified and reconciled?
- Are personnel records complete and reported with final tallies?
- Has the management team revisited the proposal's goals and objectives and done a self-appraisal of the project's success?

- Are all lists of deliverables and products (curricula, papers, presentations up to date with full bibliographic citations (including in-preparation or submitted materials)?
- Are final project participant numbers and demographics fully accounted for?
- Is an adequate system in place for tracking and documenting project graduates, publications and other useful metrics over the next 5 to 10 years?
- Has NSF been apprised of all the above?

7-14. Final Project Reports

A final project report is expected for each CREST award, irrespective of whether the same group intends to pursue phase II funding. The final project report is due within 90 days of the project end date. If no other arrangements are made, the Agreement will be considered closed with 6 months of the project end date and receipts for remuneration may no longer be received.

- Just as daily or weekly reports facilitation the writing of an annual report, a collection of accurate and complete final report.
- The final CREST report should not simply be a resubmission of previous annual reports. Rather, it should briefly summarize the year-to-year accomplishments of the award, relate these to the project's goals and objectives, and present some overarching conclusions.
- Other useful components of the final report are:
- Suggestions for future directions based on your accomplishments.
- Final lists of products (publications, curricula, presentations) and publicity derived directly from the award.
- Final numbers and demographics of participants (administrators, faculty, students, technicians) involved in the project.
- Awards and commendations.
- Evaluators' reports (if completed)
- Lessons learned, including suggestions for the processing and administration of future CREST proposals.
- Items still incomplete or pending at the time the final report is due may be submitted at a later date via FastLane or other means of delivery. If these items are expected, you should allude to them in the text of the final report.
- You may also provide late disclosures via an amended final report. However, this may not be possible once the previous final report is approved and the grant is closed. Check with your program officer for his/her preference for your particular circumstances.

- As with annual reports, final project reports are only accepted via FastLane and the report template provide should be used to facilitate proper data capture.
- The report should be designated as a final project report and should specify the entire duration of the Cooperative Agreement.
- In some cases, the final project report may be combined with the project's final (Year 5) annual report. Check with your program officer as to his/her preference.
- Check with your Executive and Research directors to confirm they have reported everything of interest to you. Ask them if there is any further information from you.

7-15. Reapplying to CREST and Continuing Project Momentum

Reapplying to CREST—[Note: at this time, projects completing their phase II CREST projects are not eligible to reapply.] Succeeding this far, you should do an honest appraisal of whether your project has succeeded as a five-year Center, or whether a continuation of effort via a second, phase II Cooperative Agreement is warranted.

[this section currently under revision]

Continuing project momentum—Project momentum is a variable that should be independent of NSF support. In a sense it is more liberating because it may not be bound by the same restrictions of the Cooperative Agreement. It is the reward of all the efforts you have put into promoting the Center and building lasting relationships on campus and in the community.

Your strategic plan and the NSF Cooperative Agreement have in large part dictated your course of action over the past five years. But your project's commitments do not begin and end with fulfilling the terms of your NSF funding.

You have worked long and hard to promote your Center. You have made long-term partnerships and developed a unique role in the research and education communities. Now is the time to "take stock" and consider what you "owe" to the various people and organizations who have helped you get this far. Consult with NSF, your CREST partners, industry partners and delegates at the university to see if there are any final commitments or expectations they have outstanding. Even if there are no further requirements, you are building linkages to assist your next proposal and assuring that the CREST will remain a respected part of the community. Also

check with your program officer from time to time. Extraneous items of interest often come up in the weeks or months after a final project report is approved.

Stay in touch with NSF. Your experience is now a valuable commodity to future proposals, site visits, merit-review panels and committees of visitors.

7-16. FAQs from CREST Post-awardees

CREST program staff encounter a number of frequently asked questions (FAQs). For the purposes of these fact sheets, such questions have been partitioned into lists most applicable before, during and after award. These are the most common questions, and the answers provided are given in the name of consistency for all applicants and awardees. Once you have browsed this list, as well as the information on the preceding fact sheets and the CREST Best Practices Manual, you should be well briefed on what makes a good CREST. Of course you may still have other questions, or may wish to suggest a new "FAQ" for these pages. In that case, you are welcome to contact the CREST program directly.

What project-related documentation must be retained and for how long?—At a minimum, all correspondence to and from NSF, financial records and reconciliation, personnel data, participant demographics, evaluation reports, prior audits and lists of final award outputs (publications, patents, presentations) should be kept on file. Since it is not unusual for a project closed for a decade or more to be reexamined, copies of these documents should be kept on file at the institution and with the project PI for at least 10 years.

How detailed should final reports be?—Final reports should revisit the goals and objectives of the proposal and explain how these goals were or were not reached. Publication, patent and presentation lists should be complete with full, searchable citations (including draft or in-process publications). Demographics of direct CREST participants, by year; research outcomes, by year; summaries of financial expenses; and a summary narrative by the PI and Co-PIs are also eligible for final reports. Except by prior agreement, final reports are due no later than 90 days after the end of the Cooperative Agreement.

When is a no-cost extension appropriate?—Contrary to popular opinion, a grantee-approved no-cost extension is not a "freebee" to be used at will by the PI. Particularly in the case of a Cooperative Agreement, temporal

accountability is as important as financial accountability. Goals and objectives, staffing levels, participant numbers and contingencies for these are all part of a good strategic plan. Beginning in Year 1, if the project staff senses a significant shortfall in project outcomes or expenses, the CREST program staff should be consulted as soon is possible. This is a good example why annual report news need not all be good news. Work with your program officer to hit your targets on time and on budget. At a minimum, a no-cost extension must be received at least 45 days prior to the end of your current grant increment.

When should I apply for a phase II CREST?—This answer will be specific to the progress of your particular CREST. It will depend on the Center's success in meeting its Phase I goals, the outcomes of site visits and reverse site visits, and the advisement of the project's advisory committees and auditors. Available program funding and the appraisal of the NSF program also are also a consideration. There should be enough overlap between the phase I and phase II projects to avoid squandering undue time or finances, but enough overlap to properly complete some phase I efforts in favor of phase II extensions. Keeping in mind the role of NSF and CREST to support cutting-edge research, phase II proposals should extend the spirit and successes of the phase I work while not being a rote duplication of the phase I proposal.

Can unexpended funds be rolled over?—This will depend on the type and amount of the unexpended funds and the details of the Cooperative Agreement. Though exceptions may arise, in general, if the grant has been administered "on time and on budget," there should not be significant unexpended funds without advance notification, justification and discussion with the NSF program officer.

Should we document how we will sustain the NSF supported efforts?—Absolutely. No amount of federal support can last forever. A plan for self-sufficiency (autonomy) should be built into the strategic plan and used to continue the project's momentum after NSF funding ends. The plans for continuing momentum should ideally begin in the final one to two years of the Cooperative Agreement. The updated status of these plans can be included in your final report. The final report itself may be amended to include late-breaking information in this regard.

What acknowledgement should be made to NSF on CREST- related publications?—Typically some version of "this work was supported in part by National Science Foundation award number 1234567" is sufficient. Interested

readers may then lookup the on-line abstract for the award to learn its details. It is appreciated, though not necessary, to specify the CREST program, as by giving attribution to “NSF award CREST-1234567”

7-17. Summary

The above information consolidates much of the content in the “Other Topics of Interest” tip sheets. Together with the CREST Best Practices Manual, it is intended to provide a broad overview of “what works” in CREST administration and what is expected from CREST grantees. Obviously there is no single “best” solution to many of these discussion topics, and no list will be considered complete and final. But there is much to be learned from this “living document” to help prospective PIs write more competitive proposals and assist CREST awardees with proper award management. We invite your input for further information or additional topics as this Manual continues its development.

7-18. Chapter References

Consultation with your NSF program officer.

The CREST program solicitation
Online at http://www.nsf.gov/pubsys/ods/getpub.cfm?nsf04574

The NSF *Grant Proposal Guide* (GPG)
Online at http://www.nsf.gov/pubsys/ods/getpub.cfm?gpg

National Science Foundation (NSF) 2003. *NSF Strategic Plan FY 2003-2008.* National Science Foundation, Arlington, VA.

NSF 99-172

OFFICE OF THE DIRECTOR

September 20, 1999

National Science Foundation Merit Review

Dear Colleagues:

Merit review is a critical component of the National Science Foundation's decision-making process for funding research and education projects. Two years ago, NSF announced changes in its merit review criteria (Important Notice No. 121, *New Criteria for NSF Proposals*, July 10, 1997). The changes reflected extensive analysis and discussion, with community input. Recommendations were considered to simplify the merit review criteria and harmonize them with the NSF strategic plan, in order to weigh a proposal's technical merit, creativity, educational impact and its potential benefits to society. This process resulted in the two criteria now in effect, which address the intellectual merit of the proposed activity and its broader impacts.

We want to ensure that the criterion relating to broader impacts is considered and addressed in proposals and reviews. We ask you -- as principal investigators who develop and submit proposals, and as experts who review proposals -- to consider both intellectual merit and broader impacts in preparing and evaluating proposals for NSF. At the same time, we will continue to strengthen NSF's internal processes to ensure that both criteria are appropriately addressed when making funding decisions.

Through use of rigorous, competitive merit review, NSF maintains high standards of excellence and accountability. It enables investments in projects that couple the best ideas from the most capable researchers and educators, with the advancement of discovery and learning and the enrichment of the science and engineering resources. The full text of the two merit review criteria and supporting explanations, from the upcoming revision to the NSF Grant Proposal Guide (NSF 00-2), are provided in the attachment.

Rita R. Colwell
Director

NSF MERIT REVIEW CRITERIA

NSF merit review criteria are listed below. Following each criterion are potential considerations that the reviewer may employ in the evaluation. These are suggestions and not all will apply to any given proposal. Each reviewer will be asked to address only those that are relevant to the proposal and for which he/she is qualified to make judgments.

Criterion 1: What is the intellectual merit of the proposed activity?

How important is the proposed activity to advancing knowledge and understanding within its own field or across different fields? How well qualified is the proposer (individual or team) to conduct the project? (If appropriate, the reviewer will comment on the quality of prior work.) To what extent does the proposed activity suggest and explore creative and original concepts? How well conceived and organized is the proposed activity? Is there sufficient access to resources?

Criterion 2: What are the broader impacts of the proposed activity?

How well does the activity advance discovery and understanding while promoting teaching, training, and learning? How well does the proposed activity broaden the participation of underrepresented groups (e.g., gender, ethnicity, disability, geographic, etc.)? To what extent will it enhance the infrastructure for research and education, such as facilities, instrumentation, networks, and partnerships? Will the results be disseminated broadly to enhance scientific and technological understanding? What may be the benefits of the proposed activity to society?

PIs should address the following elements in their proposal to provide reviewers with the information necessary to respond fully to the above-described NSF merit review criteria. NSF staff will give these elements careful consideration in making funding decisions.

Integration of Research and Education

One of the principal strategies in support of NSF's goals is to foster integration of research and education through the programs, projects and activities it supports at academic and research institutions. These institutions provide abundant opportunities where individuals may concurrently assume responsibilities as researchers, educators, and students, and where all can engage in joint efforts that infuse education with the excitement of discovery and enrich research through the diversity of learning perspectives.

Integrating Diversity into NSF Programs, Projects, and Activities

Broadening opportunities and enabling the participation of all citizens -- women and men, underrepresented minorities, and persons with disabilities -- are essential to the health and vitality of science and engineering. NSF is committed to this principle of diversity and deems it central to the programs, projects, and activities it considers and supports.

NSF 99-172

National Science Foundation

Arlington, VA 22230

Conflict-of-Interests and Confidentiality Statement for NSF Panelists

Includes members of proposal review panels; site visitors; and committee of visitors.

1. Your Potential Conflicts of Interests.

Your designation as an NSF panelist requires that you be aware of potential conflict situations that may arise. Read the examples of potentially biasing affiliations or relationships listed on the second page or back of this form. As an NSF panelist, you will be asked to review applicant grant proposals. You might have a conflict with one or more. Should any conflict arise during your term, you must bring the matter to the attention of the NSF program officer who asked you to serve as a panelist. This official will determine how the matter should be handled and will tell you what further steps, if any, to take.

2. No Use of "Insider" Information.

If your designation gives you access to information not generally available to the public, you must not use that information for your personal benefit or make it available for the personal benefit of any other individual or organization. This is to be distinguished from the entirely appropriate general benefit of learning more about the Foundation, learning from other panel members, or becoming better acquainted with the state of a given discipline.

3. Your Obligation to Maintain the Confidentiality of Proposals and Applicants.

The Foundation receives proposals in confidence and protects the confidentiality of their contents. For this reason, you must not copy, quote, or otherwise use or disclose to anyone, including your graduate students or post-doctoral or research associates, any material from any proposal you are asked to review. If you believe a colleague can make a substantial contribution to the review, please obtain permission from the NSF program officer *before* disclosing either the contents of the proposal or the name of any applicant or principal investigator.

4. Confidentiality of the Review Process and Reviewer Names.

NSF keeps reviews and your identity as a reviewer of specific proposals confidential to the maximum extent possible, except that we routinely send to principal investigators (PIs) reviews of their own proposals without your name, affiliation, or other identifying information. Please respect the confidentiality of all principal investigators and of other reviewers. Do not disclose their identities, the relative assessments or rankings of proposals by a peer review panel, or other details about the peer review of proposals.

Unauthorized disclosure of any confidential information could subject you to sanctions.

YOUR CERTIFICATION

Your Potential Conflicts.

I have read the list of affiliations and relationships (on the back of this form) that could prevent my participation in matters involving such individuals or institutions. To the best of my knowledge, I have no affiliation or relationship that would prevent me from performing my panel duties. I understand that I must contact the NSF program officer if a conflict exists or arises during my service. I further understand that **I must sign and return this Conflict Statement to the program officer before I may serve.**

Maintaining the Confidentiality of Others.

I will not divulge or use any confidential information, described above, that I may become aware of during my service.

Your Identity as a Reviewer will be Kept Confidential (Does not apply to Committee of Visitors).

I understand my identity as a reviewer of specific proposals will be kept confidential to the maximum extent possible, except that copies of written reviews that I submit will be sent to the principal investigator(s) without my name and affiliation.

Member's Name (Please Print) _____

Member's Signature _____ DATE _____

Name of Panel _____

Directorate/Division: _____

NSF Form 1230P (8/97)

File in Panel File

All Previous Editions are Obsolete

Conflict-of-Interests for NSF Panelists

Includes members of proposal review panels; site visitors; and committee of visitors.

AS A PANELIST, PLEASE REVIEW THESE EXAMPLES OF POSSIBLE CONFLICTS PERIODICALLY DURING YOUR TENURE.

1. YOUR AFFILIATIONS WITH AN APPLICANT INSTITUTION.

You may have a conflict if you have/hold/are:

- *Current employment at the institution as a professor, adjunct professor, visiting professor, or similar position.*
- *Other current employment with the institution (such as consulting or an advisory arrangement).*
- *Previous employment with the institution within the last 12 months.*
- *Being considered for employment at the institution.*
- *Formal or informal reemployment arrangement with the institution.*
- *Ownership of securities of firms involved in the proposal or application.*
- *Current membership on a visiting committee or similar body at the institution. (This is a conflict only for proposals or applications that originate from the department, school, or facility that the visiting committee or similar body advises.)*
- *Any office, governing board membership, or relevant committee chairpersonship in the institution. (Ordinary membership in a professional society or association is not considered an office.)*
- *Current enrollment as a student. (Only a conflict for proposals or applications that originate from the department or school in which one is a student.)*
- Received and retained an honorarium or award from the institution within the last 12 months.

2. YOUR RELATIONSHIP WITH AN INVESTIGATOR, PROJECT DIRECTOR, OR OTHER PERSON WHO HAS A PERSONAL INTEREST IN THE PROPOSAL OR OTHER APPLICATION.

- Known family relationship as spouse, child, sibling, or parent.
- *Business or professional partnership.*
- Past or present association as thesis advisor or thesis student.
- Collaboration on a project or on a book, article, report, or paper within the last 48 months.
- Co-editing of a journal, compendium, or conference proceedings within the last 24 months.

3. YOUR OTHER AFFILIATIONS OR RELATIONSHIPS.

- Interests of the following persons are to be treated as if they were yours: Any affiliation or relationship of your spouse, of your minor child, of a relative living in your immediate household or of anyone who is legally your partner that you are aware of, *that would be covered by any italicized items above.*
- Other relationship, such as close personal friendship, that you think might tend to affect your judgment or be seen as doing so by a reasonable person familiar with the relationship.

CREST Site Visit Guided Interview
(draft 11/04)

1. Project Data

This information summarizes the details of the grant's administration according to NSF system data.

- ❑ Award Number
- ❑ Lead Institution
- ❑ Other Institutions and Collaborators
- ❑ Principal Investigator(s)
- ❑ Co-Principal Investigator(s)
- ❑ Cognizant program officer
- ❑ Cognizant grant officer
- ❑ Project Start Date
- ❑ Project End Date
- ❑ Date(s) of previous site visits (if any)
- ❑ Date(s) of previous reverse site visits (if any)
- ❑ Date(s) of no-cost extensions (if any)

2. Background Documentation

This information summarizes the background information provided to the site visitors in advance of their arrival. Check all applicable items. Information presented for inspection by project personnel should also be noted by the visitors.

- ❑ Grant Proposal Guide
- ❑ Program solicitation
- ❑ Original proposal
- ❑ Proposal amendments
- ❑ Cooperative Agreement
- ❑ Hardcopy jacket
- ❑ Diary notes/correspondence (specify)
- ❑ Annual reports

- ❑ Final reports
- ❑ Other reports, audits, etc. (specify)
- ❑ Comments from previous site visits/COVs
- ❑ Comments from previous reverse site visits
- ❑ Specific concerns identified by NSF program staff or auditors
- ❑ Additional materials provided by project personnel (specify)

3. Site Visitor Data

This information summarizes the persons on the site visit and the administrative details of their trip.

- ❑ Site visit request initiated by (name and title)
- ❑ Date(s) of travel
- ❑ Date(s) of meeting
- ❑ Travel voucher number(s)
- ❑ Accommodation (specify)
- ❑ Rental car (specify)
- ❑ Address (including ZIP) of physical site visit meeting (list all if more than one)
- ❑ Visitor Delegation (name, title, institution, contact phone, mail, e-mail of each visitor)
- ❑ Project Delegates (name, title, institution, contact phone, mail, e-mail of each key project person met.)
- ❑ Final agenda of visit
- ❑ Other notes/circumstances pertaining to this visit

4. Research Activities

Site visitors will expect to be briefed on the project's research activities, including as appropriate: meetings with research staff; presentations about research outcomes; financial records; participant data; and tours of facilities. Also of interest will be lists of —

- ❑ Summaries of research highlights and concerns
- ❑ Projected deviations from the research plan
- ❑ Publications, including full citations
- ❑ Conferences attended, differentiated by local, regional, national and international)

- Research and industry visitors and their affiliations
- Patents received or pending from the grant
- Awards, commendations, and community commitment

5. Education Activities

Site visitors will expect to be briefed on the project's education activities, including as appropriate: meetings with faculty and students; presentations about education outcomes; financial records; participant data; and tours of classrooms or laboratories

- What is the level and type of interaction between researchers and education faculty?
- How familiar are students, office staff and technicians with the Center and its goals?
- How are students involved in the research activities?
- What is the nature of project outreach to K-12 schools? To community colleges? To industry?
- Describe the mentoring activities offered
- Describe the internship opportunities offered
- Is there a clipping file or bibliography of publicity available for the project
- Are project student graduates tracked? If so, what is their status?

6. Facilities and Equipment

This category is somewhat subjective and may be difficult to demonstrate for projects with components spread over large geographic areas. Not all facilities may be personally inspected during the site visit, but information should be readily available for inspection.

- Function, physical address, square footage and primary contact for each research facility and administrative office dedicated for the project's use
- Lists of major equipment at each facility, differentiated by grant purchase, in-kind donation or other.
- Copies of state, OSHA, insurance, fire and other certifications and compliances, as applicable

7. Participant Numbers and Demographics

Participant numbers and demographics are data referring to individuals directly involved with the project's activities—nominally staff, faculty and students at all levels but sometimes also parents, corporate partners and state or local government agencies. The key word is directly involved, not projected or potential numbers. These data should be collected for each year of the project and compared to the estimates given in the original proposal and the Cooperative Agreement. As far as is allowable, data on the demographics (gender, ethnicity, disability status, STEM field or major) should also be kept. Demographic data may also be estimated and should not be directly linked to individuals' names or identities.

- Number of K-12 students
- Number of K-12 faculty (differentiate full-time or part-time)
- Number of undergraduate students (differentiate full-time or part-time)
- Number of undergraduate faculty (differentiate full-time or part-time)
- Number of graduate students (differentiate full-time or part-time)
- Number of graduate faculty (differentiate full-time or part-time)
- Key project staff (differentiate by administration, research, executive functions, including technicians and interns, full-time or part-time)
- Other industry or community partners, as applicable.

8. Financial Reporting

Up-to-date records of all accounts, especially including summaries of research project expenses and summaries of unobligated funds, should be made available to the site visitors, who may ask for clarification about—

- Reconciliation of financial accounts
- Cost-share documentation (if applicable)
- Documentation of in-kind donations (if applicable)
- Research project expenses and projected expenses
- Documentation of receipts submitted and estimates of receipts expected
- Compliance of expenditures with the Cooperative Agreement or written justification for discrepancies
- Salaries and job descriptions of key personnel, as related to the proposal and the Cooperative Agreement
- Summaries of stipends, fringe benefits, or other special payments to individuals
- Documentation of major equipment purchases

- Documentation (e-mail, FastLane receipt or other) of requested or declared changes in the project budget, justification, or shortfalls or excesses in expected expenses.

9. SWOT Analysis

Based on the above information, visitors will prepare an analysis of the project's Strengths, Weaknesses, Opportunities, and Threats to continued existence (SWOT). This information will be submitted to the program staff and kept on file with the award jacket.

- Strengths
- Weaknesses
- Opportunities
- Threats
- Other notes and observations of the visitors
- Other concerns expressed by project staff
- Other concerns expressed by program staff

10. Concerns and Recommendations

Visitors will also make recommendations to the program staff about the function and appearance of the project and its constituent parts. As warranted, the program officer will follow-up these recommendations by discussing them with the project staff. Project staff will be afforded the opportunity to respond to the visitors' comments and recommendations and to propose corrective actions or measures for further improvement.

As with the merit-review process, discussion will include—

- The strengths of the project's intellectual merits
- The weaknesses of the project's intellectual merits
- The strengths of the project's broader impact
- The weaknesses of the project's broader impact

Of particular interest will be—

- The project's compliance to the proposed scope of work (or documentation/justification to the contrary)
- The project's compliance with the Cooperative Agreement (or documentation/justification to the contrary)
- The project's compliance with the goals of the program, to include the development of world-class research capacity at U.S. minority-serving institutions and the collaboration of research, education and industry

activities to the benefit of minorities in science, technology, engineering and mathematics

CREST Reverse Site Visit Guided Interview
(draft 11/04)

The main benefit of a face-to-face meeting with panelists—versus the submission of a written report—is that is allows the reverse-site-visit (RSV) panel to listen to the project staff in their own words, then guide the proceedings according to specific issues or concerns that may arise.

However, unlike a site visit, the project staff will not be on their home campus with ready access to files and personnel. Responses to a variety of questions should be prepared, and supported by reasonable data. The agenda of the meeting, expected presentation format, and any unusual information requested by NSF or the RSV panel will be provided to the project staff well in advance of the reverse site visit. The intent of the process is for project staff to hear the concerns of NSF via the reverse site visit and use this advisement to make changes in the administration of the grant. Being prepared at the meeting will lessen the amount of followup correspondence that is required in the days and weeks following the reverse site visit.

1. Background Documentation

The following materials should be well familiar to the project personnel as well as the RSV panelists. It need not be brought to the meeting, since in-house copies will be available at NSF and, if necessary, distributed to the RSV members by NSF well in advance of the meeting.

- ❑ Grant Proposal Guide
- ❑ Program solicitation
- ❑ Original proposal
- ❑ Proposal amendments
- ❑ Cooperative Agreement
- ❑ Annual reports
- ❑ Final reports
- ❑ Other reports, audits, etc. (specify)
- ❑ Comments from previous site visits/COVs
- ❑ Comments from previous reverse site visits
- ❑ Specific concerns identified by NSF program staff or auditors

2. Research Activities

RSV panelists will expect to be briefed on the project's research activities, including as appropriate: presentations about research outcomes; participant data; publication and patent lists; and the capacity of key facilities. Also of interest will be —

- Summaries of research highlights and concerns
- Projected deviations from the research plan
- As handouts: Publications, including full citations; conferences attended, differentiated by local, regional, national and international); research and industry visitors and their affiliations; patents received or pending from the grant; awards, commendations, and community commitment

3. Education Activities

Site visitors will expect to be briefed on the project's education activities, including as appropriate: presentations about education outcomes.

- What is the level and type of interaction between researchers and education faculty? How are students involved in the research activities?
- Describe the nature of project outreach to K-12 schools? To community colleges? To industry?
- Describe the mentoring activities offered
- Describe the internship opportunities offered
- As handouts: Is there a clipping file or bibliography of publicity available for the project. Are project student graduates tracked? If so, what is their status?

4. Facilities and Equipment

This category is somewhat subjective and may be difficult to demonstrate for projects with components spread over large geographic areas. Not all facilities may be personally inspected during the site visit, but information should be readily available for inspection.

- As handouts: Function, physical address, square footage and primary contact for each research facility and administrative office dedicated for the project's use; Lists of major equipment at each facility, differentiated by grant purchase, in-kind donation or other; copies of state, OSHA, insurance, fire and other certifications and compliances, as applicable

5. Participant Numbers and Demographics

Participant numbers and demographics are data referring to individuals directly involved with the project's activities—nominally staff, faculty and students at all levels but sometimes also parents, corporate partners and state or local government agencies. The key word is directly involved, not projected or potential numbers. These data should be collected for each year of the project and compared to the estimates given in the original proposal and the Cooperative Agreement. As far as is allowable, data on the demographics (gender, ethnicity, disability status, STEM field or major) should also be kept. Demographic data may also be estimated and should not be directly linked to individuals' names or identities.

- As handouts and for each year of the project, provide the number of: K-12 students; K-12 faculty (differentiate full-time or part-time); undergraduate students (differentiate full-time or part-time); undergraduate faculty (differentiate full-time or part-time); graduate students (differentiate full-time or part-time); graduate faculty (differentiate full-time or part-time); key project staff (differentiate by administration, research, executive functions, including technicians and interns, full-time or part-time); and other industry or community partners, as applicable.

6. Financial Reporting

Up-to-date records of all accounts, especially including summaries of research project expenses and summaries of unobligated funds, should be made available to the RSV panel, who may ask for clarification about—

- Reconciliation of financial accounts
- Cost-share documentation (if applicable)
- Documentation of in-kind donations (if applicable)
- Research project expenses and projected expenses
- Documentation of receipts submitted and estimates of receipts expected
- Compliance of expenditures with the Cooperative Agreement or written justification for discrepancies
- Salaries and job descriptions of key personnel, as related to the proposal and the Cooperative Agreement
- Summaries of stipends, fringe benefits, or other special payments to individuals
- Documentation of major equipment purchases

- Documentation (e-mail, FastLane receipt or other) of requested or declared changes in the project budget, justification, or shortfalls or excesses in expected expenses.

7. Concerns and Recommendations

Based on the above information and the presentation of project staff, the RSV panel will summarize their concerns and will often propose a prescriptive list of action items or corrective measures. It is expected that the project staff will address the concerns of the RSV, or provide justification why not.

As with the merit-review process, discussion will include—

- The strengths of the project's intellectual merits
- The weaknesses of the project's intellectual merits
- The strengths of the project's broader impact
- The weaknesses of the project's broader impact

Of particular interest will be—

- The project's compliance to the proposed scope of work (or documentation/justification to the contrary)
- The project's compliance with the Cooperative Agreement (or documentation/justification to the contrary)
- The project's compliance with the goals of the program, to include the development of world-class research capacity at U.S. minority-serving institutions and the collaboration of research, education and industry activities to the benefit of minorities in science, technology, engineering and mathematics

Tell us a little about yourself

What kind of information is needed in project reports? How will these data be used? When are project reports due? How should Federal support be acknowledged? When is project outreach "good enough"? This overview addresses many of the questions received by program officers. Although drawn from broad common experience, exceptions to these guidelines are inevitable. Specific questions for particular programs may not be included here. If you are new awardee or are unfamiliar with the expectations of your particular program, answers are just a phone call or an e-mail away. A working dialogue with your program officer is prerequisite to effective information exchange and the successful completion of your NSF-funded research or education project.

Plan the Work, Work the Plan

The consideration of proposals during merit review is based on two fundamental criteria stipulated by the National Science Board. To paraphrase these criteria, Criterion 1 asks: *What is the Intellectual Merit of the Proposed Work?* Criterion 2 asks: *What are the Broader Impacts of the Proposed Work?* Addressing these two criteria in the description of your work provides a good initial estimate of the project's *viability*.

A related consideration is uniqueness. That is, how well does the work advance or improve upon previous efforts? What is its *contribution* to the knowledge base? Experience shows that every successful project has a defined framework. In practice this structure may be produced in any number of ways, but a fundamental consideration is the roles and responsibilities of the various individuals and institutions involved. Determining such roles at the proposal stage provides assurance that sufficient project *direction* is in place. Next, a reviewer may want to see what partnerships the project has in place. Whether your project is part of a large alliance or operates on a single campus, partnerships demonstrate the community's *commitment* to the project, which ultimately will determine the project's sustainability irrespective of current or future Federal support.

Collectively and individually, these basic considerations lead to the kind of information requested from your work before and after a grant is awarded.

Reporting and Evaluation

Reporting and evaluation objectively communicate the progress of your project. For the funding agency, the merits of project reports are the best way to document program effectiveness. Project reports, immediate accomplishments (often called products or *outputs*) and long-term, measurable changes (often called systemic changes or *outcomes*) are the most direct measures of a project's success. It may surprise you to consider that "success" does not necessarily mean "spectacularly positive". There are valuable lessons to be learned from failures and disappointments. Reporting these, along with constructive evaluations and alternatives, may lead to a better solution for you or the research community.

Annual reporting obligations are not intended to be an undue burden on the investigator's time. In general, keeping a daily or weekly log of the project's efforts provides a source of information that can be summarized and transferred to the Fastlane report template in an hour or two and, usually, in less than 20 pages. Again, the requirements of your particular program may differ.

What to Report - Remember GPRA

Consider the following observation of Michael Patton (1982), which speaks to the heart of nearly every academic exercise:

> *If there is nothing you are trying to find out, there is nothing you will find out.*

The National Science Foundation (NSF) is unique in its role to support basic research in the United States. In the context of Federal reporting guidelines, the process of documenting research outcomes becomes a bit more rigorous, as illustrated in this excerpt from Osborne and Gaebler's *Reinventing Government* (1992):

> *What gets measured, gets done.*
> *If you don't measure results,*
> *You can't tell success from failure.*
> *If you can't recognize failure, you can't correct it.*
> *If you can't see success, you can't reward it.*
> *If you can't see success, you can't learn from it.*

The need to chart measurable gains in the government's performance led to 1993's Government Performance and Results Act (GPRA). A decade later, GPRA remains as an important cornerstone for documenting government responsiveness and measurable outcomes. The indicators for Fiscal Year 2004 are summarized in Exhibit 1.

The National Science Foundation's strategic goals for PEOPLE, IDEAS, and TOOLS relate directly to corresponding GPRA categories. As a project manager, you should be aware that these indicators will provide the basis for your program officer's reporting on the effectiveness of his or her program. Accordingly, questions about your project may be expected in these areas.

Note: Any given project is assigned to one or more GPRA indicators by the cognizant program officer and only *after* the award is made. *Since the indicators change slightly from year to year, you should not try to speculate or suggest which indicators should apply to your project; your program officer will determines such things, as appropriate*.

Exhibit 1

FY 2004 Strategic Goals and GPRA Indicators

PEOPLE GOAL

A DIVERSE, COMPETITIVE, AND GLOBALLY ENGAGED U.S. WORKFORCE OF SCIENTISTS, ENGINEERS, TECHNOLOGISTS AND WELL-PREPARED CITIZENS

Goal Indicators

P1: Promote greater diversity in the science and engineering workforce through increased participation of underrepresented groups and institutions in all NSF programs and activities.

P2: Support programs that attract and prepare U.S. students to be highly qualified members of the global S&E workforce, including providing opportunities for international study, collaborations and partnerships.

P3: Develop the Nation's capability to provide K-12 and higher education faculty with opportunities for continuous learning and career development in science, technology, engineering and mathematics.

P4: Promote public understanding and appreciation of science, technology, engineering, and mathematics, and build bridges between formal and informal science education.

P5: Support innovative research on learning, teaching and mentoring that provides a scientific basis for improving science, technology, engineering and mathematics education at all levels.

IDEAS GOAL

DISCOVERY ACROSS THE FRONTIER OF SCIENCE AND ENGINEERING, CONNECTED TO LEARNING, INNOVATION, AND SERVICE TO SOCIETY

Goal Indicators

I1: Enable people who work at the forefront of discovery to make important and significant contributions to science and engineering knowledge.

I2: Encourage collaborative research and education efforts – across organizations, disciplines, sectors and international boundaries.

I3: Foster connections between discoveries and their use in the service of society.

I4: Increase opportunities for underrepresented individuals and institutions to conduct high quality, competitive research and education activities.

I5: Provide leadership in identifying and developing new research and education opportunities within and across S&E fields.

I6: Accelerate progress in selected S&E areas of high priority by creating new integrative and cross-disciplinary knowledge and tools, and by providing people with new skills and perspectives.

TOOLS GOAL

BROADLY ACCESSIBLE, STATE-OF-THE-ART S&E FACILITIES, TOOLS AND OTHER INFRASTRUCTURE THAT ENABLE DISCOVERY, LEARNING AND INNOVATION

Goal Indicators

T1: Expand opportunities for U.S. researchers, educators, and students at all levels to access state-of-the-art S&E facilities, tools, databases, and other infrastructure.

T2: Provide leadership in the development, construction, and operation of major, next-generation facilities and other large research and education platforms.

T3: Develop and deploy an advanced cyber-infrastructure to enable all fields of science and engineering to fully utilize state-of-the-art computation.

T4: Provide for the collection and analysis of the scientific and technical resources of the U.S. and other nations to inform policy formulation and resource allocation.

T5: Support research that advances instrument technology and leads to the development of next-generation research and education tools.

Other Useful Information to Include in Reports

GPRA indicators are a good place to start when deciding what to report about a given project, but there is much more information your program officer would like to know. From time to time, NSF features awarded projects via press releases, award data, program summaries, speeches, and articles about NSF initiatives. In such instances it is especially important for NSF staff to be aware of substantive project outcomes, often in-between the usual annual reporting dates. Exhibit 2 provides some useful examples of information that will help ensure NSF highlights the things you feel are accurately representative of your work.

Exhibit 2

Other Useful Information to Include in Reports

In the past year*, what are the 3 most significant accomplishments of your project?

In the past year, what are the 3 largest concerns or surprises that have arisen in your project?

In the past year, how has your project directly or measurably changed the academic climate of your institution?

If applicable, describe how the project has deviated from its intended progress in the past year, or how you anticipate it may deviate in the year to come? Why?

Describe the aspects of your program (pedagogy, methods, products, etc.) that may be considered ready for regional or national distribution as models or exemplars, either now or within the next year.

Describe your knowledge of or direct contact with current, similar projects in your state or neighboring states.

Describe your project's involvement with: a) industry, b) outside laboratories, c) international partners, and d) potential feeder schools, including the number of students and faculty directly involved in each activity.

If not discussed above, describe the number of actual participants in the: a) mentoring, and b) recruitment efforts of your project.

Provide specific data, as such are available, on actual student enrolment in your project. How much of an increase (or decrease) does this represent over the previous year? Over initial (baseline) levels? Compared to similar populations without NSF support?

For your project, include the number of successful graduates in the past year, the number anticipated in the next year, and (for final reports) the overall number of graduates produced by your project.

** Substitute "overall" for "in the past year" for final reports.*

Acknowledging Federal Support

Guidelines for acknowledging general NSF support are detailed in Section 19 ("Publications") in the NSF publication *Grant General Conditions* (GC-1), and the *Grant Proposal Guide* (GPG, NSF 04-2), Chapter VI, Section I ("Acknowledgment of Support and Disclaimer") available online and reproduced below.

I. ACKNOWLEDGMENT OF SUPPORT AND DISCLAIMER

An acknowledgment of NSF support and a disclaimer must appear in publications (including Web pages) of any material, whether copyrighted or not, based on or developed under NSF-supported projects:

"This material is based upon work supported by the National Science Foundation under Grant No. (grantee must enter NSF grant number)."

NSF support also must be orally acknowledged during all news media interviews, including popular media such as radio, television and newsmagazines.

Except for articles or papers published in scientific, technical or professional journals, the following disclaimer must be included:

"Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation."

It is also helpful to mention the award number, so that interest parties can reference the on-line abstract material for your project at nsf.gov. The search component of the NSF web site (http://www.nsf.gov/home/search.htm) offers full-text and fielded searches of all NSF awards since 1989. Project summaries (sponsor, investigator, contact info, NSF program association, and Abstract) can be browsed individually or grouped by institution, program, or state. NSF documents, staff, and Directorates can also be searched from this site. In addition, NSF's FastLane system (http://www.fastlane.nsf.gov/a6/A6Start.htm) provides a variety of search options, producing lists of recent awards, and lists of awards by state, program, and institution. As appropriate, awardees may also mention the specific and correct NSF program(s) responsible for their award as part of their acknowledgment.

Use of the NSF Logo

The official NSF logo is available electronically in various file formats for use by members of the public who wish to provide a link to an NSF website or to acknowledge NSF assistance as required by the "Publications" article of the Foundation's *Grant General Conditions*. No special permission is required from the National Science Foundation to reproduce these images. More information and links to the electronic files are available from the URL: http://www.nsf.gov/home/graphics/start.htm

Web Sites

Keeping your program officer responsible for your award apprised of the current and accurate uniform resource locator (URL) of your project's web site(s) is recommended. In addition, awardees are encouraged to provide a hyperlink from their web pages to a current, bibliography-style listing of all publications, presentations, products, documents, workshops, seminars, meetings, lectures, and other materials produced in whole or in part from their NSF support. This will provide NSF staff, the general public, and other interested parties with an accurate summary of your project's latest results, proper citations for products and publications, and ongoing impact. In our experience, the provision of such a resource provides NSF program officers with ready listing of the latest and most relevant project outcomes. Additionally, such listings may lessen the amount of detailed information the principal investigator is required to provide elsewhere regarding the project's activities. You may also elect to include a hyperlink to the NSF home page or the web page for the specific NSF program(s) from which your funding was received.

Audio and Video

NSF-funded activities are often featured as stories on radio and television broadcasts. Project staff are encouraged to keep an archive of project publicity received via print and electronic media. While it is usually not required, many awardees elect to use video production resources to create summaries or highlights of their activities. If not previously discussed within the scope of your proposal, we suggest the following for prepared video programming:

- We encourage you to produce the highest quality master tape permitted by your budget and resources. If your video can be clearly presented in venues as diverse as meeting rooms, television broadcasts, and video-conferences, its value for outreach purposes will be enhanced.
- Organize your message and present it succinctly. Tell a compelling story with a clear narrative, which is generally more informative than unstructured photo montages or musical overtures.
- Provide enough detail to be informative to a layperson but avoid being so specific that the useful "lifespan" of your program is too short. Videos longer than 15 minutes can often be complemented by shorter, summary versions of the same content.
- Address the broadest possible audience. Not everyone who views your program will be familiar with all the details of the award.
- Avoid using previously produced (copyright protected) video footage, soundtrack music, or narration unless full permission for their use have been secured and documented by the video's producer. Appropriate recognition of the project's participants, staff, and producers should be provided as determined by prior agreement.
- Recognition of NSF support and, as appropriate, mention of the NSF program responsible for the work depicted is appreciated.

***Tip:** Looking up the online abstract for your award on nsf.gov provides a quick, reliable confirmation of whether the basic award data (PIs, co-PIs, sponsor, beginning and end date) are correct for your project. If not, contact your program officer for clarification.*

Other Media

In addition to text presentations and electronic media, you may have other products, photos, reports, clippings, and research or instructional materials to share with your program officer. Before sending these materials, it is a good idea to check with the recipient to confirm that they have sufficient archive/library storage available. High-quality, engaging photos of your project work are often appreciated, but should be provided with appropriate captions and a statement from the photographer (or in, some cases, the participants) authorizing NSF reproduction and use. Check with your program officer to see whether he or she has a preferred format for receiving photos and electronic files.

When to Report

Reporting requirements for your particular grant may be stipulated in your award agreement, specified by your program officer or modified by approved no-cost extensions or amendments. In general, annual project reports are due at approximately 12-month intervals from the time your grant commences. Final reports are due no later than 90 days after the award's end date. All official reports must be submitted electronically via Fastlane (www.fastlane.nsf.gov) using the on-line report template (see Exhibit 3).

Exhibit 3

The Fastlane Template

The Fastlane report template is designed as a best-fit solution to accommodate the wide spectrum of NSF program needs. Considerations when completing the template include:

Check the type of report. Is the designation of annual (or final) report correct? Do the specified dates indicate the proper interval with no gaps or overlaps with previous reports for this project?

Specify ontributions of Key Personnel. Are the contributions of key staff sufficiently detailed? Have students been involved significantly in the project's operation?

List organizational Partners. Avoid exhaustive, non-specific rosters. Specify key partners and their respective contributions

Avoid file attachments. It is to your advantage to complete the Fastlane template as thoroughly as possible, completing all of the sections provided within the form and avoiding extraneous information or repeated references to voluminous, catch-all supplements.

Be aware of file compliance. The information you input to Fastlane is converted to Portable Document Format (.PDF). This means you should avoid using specialized fonts, which may result in bullet points and punctuation being corrupted before your program officer receives the file. Improperly formatted tables and lists may become illegible and certain graphics may not transfer properly. If in doubt, pre-test theconversion of your source file to .PDF using Adobe Acrobat 4.0 or higher.

Use input boxes properly. Not all Fastlane input boxes "wrap" text input to the displayed window. Placing a hard return at the end of each line to keep the information in view will result in a narrow, elongated block of text that is often hard to read. Composing the information offline, then copying it into the template should allow better margin-to-margin flow.

Report products fully and completely. Publications should be given full, searchable bibliographic references. Presentations and workshops should include titles, authors, date and location, as well as information about the size and composition of the audience. Partial, anecdotal, or incomplete references contribute little to the information content of your report.

Provide useful demographics. It may not be practical to list all participants in a project, but for classroom enrollments or conference presentations, it is a good idea to list the number of direct participants in the activity and their role (faculty, student, etc.)

Check your use of human subjects and hazardous materials. It is a good idea to review, on an annual basis, the various certifications your project requires for the use of human subjects and hazardous materials. Check with your institutional review board (IRB) for details.

Avoid redundancy. The last report entered for the project is readily available in Fastlane. Avoid the temptation to simply add a few updates to what is there and resubmit it as a new report. Annual reports should list only the products and activities for the specified report interval. Final reports should provide a chronological summary of all project accomplishments with a minimum of annotation to "see attached" or "see previous reports."

Be concise. As mentioned above, a concise report following the report template can be produced without undue effort. Goals and Objectives, nominally part of the proposal or proposal abstract, usually need not be reiterated in reports. Your report should focus on activities and outcomes (both good and bad) for the indicated period. It should provide the essential information to your program officer and apprise him or her of anticipated future needs or amended progress plans.

What is "Enough" Outreach?

In consideration of GPRA, there is an increased expectation to increase the dissemination of realized short- and long-term outcomes generated by all federally funded projects. It is advisable for products from your award to be of use to the broadest appropriate audience and to be made accessible to all individuals within that audience regardless of their ability.

Every project should aspire to further the knowledge base, contributing new discoveries to appropriate venues. Celebrating that achievement should go well beyond the reporting obligations of your award. Publications, products, and lists of proven-good practices are not required components of all awards, but are a good idea.You should also list notable outreach activities for each year of your award and include citations or clippings from your media coverage.

"Building a web site" or "distributing litrature" are common suggestions in proposals, but is this effective communication or simply passive broadcasting? Ideally, your original proposal will have specific suggestions for information dissemination and external evaluation. Researchers and educators working with minorities, women, persons with disabilities and other underserved populations should not hesitate to publish the results of their work in mainstream arenas, calling attention to the merits for all students and practitioners. Just as merit review answers the question, *is this a good idea?* proper project evaluations and publications in peer-reviewed journals answer the question, *are these good results?*

References

Government Performance and Results Act (GPRA). See: http://www.whitehouse.gov/omb/mgmt-gpra/gplaw2m.html

National Science Foundation Strategic Plan, 2003-2008. See http://www.nsf.gov/od/gpra/

Osbourne, D. and T. Gaebler (1992). *Reinventing Government: How the Entrepreneurial Spirit Is Transforming the Public Sector*. Plume Publishing, 432 pp.

Patton, MQ (1982). *Practical Evaluation*. Sage Publications, 320 pp.

In science, all facts, no matter how trivial or banal, enjoy democratic equality.
Mary McCarthy, On the Contrary (1961)

NSF's Electronic Information Systems and Contact Information

Contact Information

National Science Foundation	http://www.nsf.gov
Division of Human Resource Development (HRD)	http://www.ehr.nsf.gov/hrd/
Division of Grants and Agreements (DGA)	http://www.nsf.gov/bfa/dga/
National Science Board (NSB)	http://www.nsf.gov/nsb/
NSF Staff Directory	http://staff.nsf.gov/
HRD Staff Directory	http://staff.nsf.gov/orgpage.cfm?key=19

Fastlane

NSF's Fastlane system must be used to submit proposals, project reports, requests, and related official correspondence to the Foundation. Fastlane may also be used to search awards and provide summary lists by state, program, or institution.

Fastlane home page	http://www.fastlane.nsf.gov
Test server (for demonstration - no password required)	http://www.fldemo.nsf.gov
User guides	http://www.fastlane.nsf.gov/a0/about/instructions.htm
NSF requirements for PDF files	http://www.fastlane.nsf.gov/a1/pdfcreat.htm
Fastlane list of all NSF programs	https://www.fastlane.nsf.gov/servlet/A6QueryPgm
NSF Fastlane Help Desk	Phone: 800-673-6188 or 703-292-8142 e-mail: fastlane@nsf.gov
Division of Human Resource Development	Phone: 703-292-8640 HRD Fastlane e-mail: hrdfl@nsf.gov

Award Information

Guide to search tools	http://www.ehr.nsf.gov/hrd/award.asp
On-line abstracts of all NSF awards	http://www.fastlane.nsf.gov/a6/A6Start.htm

Frequently Asked Questions

Preparing and submitting proposals	http://www.nsf.gov/bfa/cpo/policy/ques.htm
Award administration	http://www.nsf.gov/bfa/dga/faq.htm

NSF Publications

Online Document Search	http://www.nsf.gov/cgi-bin/pubsys/browser/odbrowse.pl
Grant Proposal Guide	http://www.nsf.gov/cgi-bin/getpub?gpg
Guide to Programs	http://www.nsf.gov/cgi-bin/getpub?gp
NSF E-Bulletin (program deadlines)	http://www.nsf.gov/home/ebulletin/
Science and Engineering Indicators (2002)	http://www.nsf.gov/sbe/srs/seind02/start.htm
Committee on Equal Opportunities in Science and Engineering (CEOSE)	http://www.nsf.gov/od/ceose/start.htm

NSF Logos and Images of the NSF Building

(for use in publications and on web sites)

Color and black-and-white logos	http://www.nsf.gov/home/graphics/start.htm
Color logos for white backgrounds	http://www.nsf.gov/home/icons/logos/logoswh.html
NSF Office of Legislative and Public Affairs (OLPA)	http://www.nsf.gov/od/lpa/

About HRD

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Projects supported by HRD have a strong focus on partnerships and collaborations in order to maximize the preparation of a well-trained scientific and instructional workforce derived from our target constituents:

- Minorities and Minority-Serving Institutions
- Women and Girls
- Persons with Disabilities

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http://www.ehr.nsf.gov/EHR/HRD/

Alliances for Graduate Education and the Professoriate (AGEP)

Centers for Research Excellence in Science and Technology (CREST)

Research on Gender in Science and Engineering (GSE)

Historically Black Colleges and Universities - Undergraduate Program (HBCU-UP)

**Historically Black Colleges and Universities
Research Infrastructure for Science and Engineering (HBCU-RISE)**

Louis Stokes Alliances for Minority Participation (LSAMP)

Model Institutions for Excellence (MIE)

**Presidential Awards for Excellence in Science, Mathematics,
and Engineering Mentoring (PAESMEM)**

Research in Disabilities Education (RDE)

Rural Systemic Initiatives (RSI)

Tribal Colleges and Universities Program (TCUP)